1. INTRODUCTION

Material Health is the cornerstone of the Cradle to Cradle (C2C) Certified™ Products Program. The choice of fibres, dyes, finishes and process chemicals has wide-ranging ramifications: it determines if the apparel can eventually be safely composted or reused in industry (Material Reutilisation); it affects the amount of energy required for making garments (Renewable Energy and Carbon Management); it affects the amount of water used and the quality of the wastewater (Water Stewardship); and it influences the health and well-being of the workers, the communities surrounding the factories, and the customers.

APPAREL CONTEXT

Many of the chemicals used in today’s apparel industry are uncharacterised (their risks are unknown) or potentially harmful to the health of workers, local communities, and/or end-users. In addition, many of the chemical ingredients prevent garments from being safely compostable or usefully recyclable.

The major concerns are these:
- halogenated organic dyestuffs (involving the presence of a non-hydrolysable carbon-halogen bond; i.e. a fluorine, chlorine, bromine, or iodine bond)
- skin-sensitising dyestuffs (inducing an allergic response)
- dyebath and process chemicals that have high toxicity and that end up in effluent
- residues persisting either in bio-based fibres (pesticides in conventional cotton, wool, or linen) or in synthetic fibres (e.g. antimony trioxide catalyst residue in polyethylene terephthalate, or PET)
- stain-proofing, anti-soiling, and waterproofing treatments based on PTFE (Teflon) chemistry

DEMAND FOR SAFER CHEMISTRY

Images and stories abound of toxic discharges from garment factories, and have come to symbolise what is wrong with the current apparel industry. End customers are beginning to hold retailers accountable, and high-visibility initiatives are emerging, such as Greenpeace’s Detox Campaign. In response, brands have begun working together to develop stricter chemistry criteria, with a view to eliminating the most hazardous chemicals and improving wastewater discharges.

ASPIRATION OF CRADLE TO CRADLE

Eliminate all toxic and undefined chemicals so that materials are suitable for safe, continuous cycling.

1 Cradle to Cradle Certified™ is a certification mark licensed by the Cradle to Cradle Products Innovation Institute
### Table 2: List of green-chemistry-focused initiatives

<table>
<thead>
<tr>
<th>Initiative</th>
<th>Emphasis</th>
<th>Major Brands Involved</th>
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<tbody>
<tr>
<td>Bluesign</td>
<td>Similar to the approach of the C2C Certified Products Program, but with different rating systems and endpoints; Bluesign studies the combination of hazard and exposure, to determine the risk posed by ingredients and to help in optimising formulations</td>
<td>Adidas, Columbia, GStar Raw, Patagonia, Lands’ End, Puma, Nike, Lululemon, Eileen Fisher, and others</td>
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<tr>
<td>ZDHC</td>
<td>Based on a Manufacturing Restricted Substances List to eliminate ingredients of concern, particularly from wastewater</td>
<td>Nike, Adidas, Gap, Inditex, Kering, Levi Strauss, Marks &amp; Spencer, Nike, Puma, C&amp;A, Esprit, H&amp;M, GStar Raw, PVH, Primark, and others</td>
</tr>
<tr>
<td>Detox Campaign</td>
<td>A Greenpeace initiative to get brands to adopt a Manufacturing Restricted Substances List and eliminate those substances from their operations by 2020 (with corresponding transparency and management plans); also, to achieve a global ban on PFCs</td>
<td>Inditex, Benetton, H&amp;M, C&amp;A, Fast Retailing, G-Star Raw, Adidas, Levi Strauss, Primark, Puma, Marks &amp; Spencer, Nike, Esprit, Li-Ning, and others</td>
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<tr>
<td>HIGG Material Sustainability Tool (MSI)</td>
<td>Delivers a holistic overview of a product’s sustainability performance; HIGG includes in its analysis green-chemistry considerations, and recognises many of the green-chemistry certifications such as Oeko-TEX Standard 100</td>
<td>Adidas, Fast Retailing, Esprit, Eileen Fisher, Gap, H&amp;M, Kering, Hanes, Lands’ End, Levi Strauss, Lululemon, Nike, Patagonia, Puma, PVH, Under Armor, VF Corp, and others</td>
</tr>
<tr>
<td>CHEM-IQ</td>
<td>Tests samples for the presence of 400 chemicals; if the samples are above set levels, VF Corp works with suppliers to optimise the chemistry</td>
<td>Developed by VF Corp with NRDC</td>
</tr>
<tr>
<td>GreenScreen for Safer Chemicals</td>
<td>Focuses on hazard profiling (only) of chemicals, and on developing alternatives to the most objectionable</td>
<td>Nike, Levi Strauss, and others</td>
</tr>
<tr>
<td>The Sustainability Consortium</td>
<td>Focuses on optimising chemistry to reduce water pollution, as well as on reducing water and energy consumption</td>
<td>Walmart, Hanes, Marks &amp; Spencer, Wrangler, and others</td>
</tr>
<tr>
<td>Oeko-TEX Standard 100</td>
<td>Tests products for ingredients of concern, via four kinds of exposure</td>
<td>Esquel, Hanna Andersson, Pottery Barn, Fruit of the Loom, and others</td>
</tr>
</tbody>
</table>

The C2C Certified Products Program aligns with the goals of all the programmes above, specifically in promoting safe chemistry; however, it goes deeper into the supply chain, and integrates “design for next use” into the chemistry itself.
MATERIAL HEALTH

BENEFITS TO MANUFACTURERS

The C2C Certified Products Program can help manufacturers by:

- assessing apparel ingredients throughout the supply chain for toxicity and usage risks
- identifying ways of optimising product chemistry
- providing third-party verification of product-sustainability claims

2. C2C CERTIFIED CRITERIA FOR MATERIAL HEALTH

The four components of the C2C Certified criteria for Material Health are as follows:

A. knowing the biological or technical “metabolism”
B. confirming the absence of Banned List chemicals
C. knowing what percentage of a product’s Bill of Materials (BoM) is characterised (i.e. has a known risk profile)
D. having an optimisation plan for any X-assessed materials

A. Determining the “metabolism”

C2C Certified products eliminate the concept of waste, in the expectation that products and ingredients will be feedstock for new production at the end of each use phase. For all achievement levels, C2C Certified products are categorised by the “metabolism” in which they are designed to cycle; optimisation ensures that both the design and the chemical ingredients support and facilitate that cycling.

- **Biological “nutrients”:** the materials are designed to return safely to the soil, as a “soil amendment” (compost) that could be used to grow new biological materials. The relevant materials here are those that can be consumed by biological processes; e.g. cotton and paper.
- **Technical “nutrients”:** the materials are designed to return to industry for remanufacture at the same quality level or higher. The relevant materials here are those that cannot be consumed by biological processes; e.g. metals and plastics. Note: bio-plastics are regarded as technical nutrients if they remain in technical cycles, even though they come from biological sources.

As part of the process, the assessor will annotate the BoM with an assessment of whether the material is a biological or technical nutrient.

B. Confirming the absence of Banned List chemicals

For a product to meet C2C Certified criteria, it must show that it does not contain certain specified chemicals as intentional inputs above 1000 parts per million (ppm). There are two lists of these banned chemicals: one for technical nutrients and one for biological nutrients. Banned lists can be found in the [C2C Certified Product Standard](#).

For BASIC level certification, manufacturers need to file a declaration that they have not intentionally added Banned List ingredients in concentrations above 1000 ppm. For BRONZE level and above, detailed BoMs may take the place of manufacturers’ declarations.
C. Compiling a Bill of Materials

For C2C certification, detailed information is required for parts or materials present in concentrations of 100 ppm or greater. The assessor might have to check with several suppliers in earlier stages of the supply chain. At each stage, the assessor will request the following information on all ingredients:

• Name of each chemical or specific manufacturer or trade name (and grade, in the case of purchased chemicals or chemical mixtures)
• Unique CAS Number for all raw chemicals
• Concentration or concentration range of each chemical or chemical mixture
• The function that each chemical or chemical mixture serves within the material or product
• The percentage of recycled content, if any, including indication of type (post-end customer or post-industrial)
• The concentrations of lead, mercury, hexavalent chromium, cadmium, pigments, dyes and other colorants, phthalates, halogenated organics, and scarce elements or substances specified in the Material Health Assessment Methodology document (e.g. indium, gold, diamond) when present at any concentration
• Process chemicals used that are textile auxiliaries (i.e. textile process chemicals)
D. Devising an optimisation plan

Some ingredients may be X-assessed (i.e. they consist of or contain highly problematic chemicals, from a C2C Certified perspective) or GREY-assessed (i.e. they cannot undergo a full assessment, owing to incomplete information). For materials containing such ingredients, manufacturers need to create an optimisation strategy if they are to secure BRONZE and SILVER level certification for a product. For GOLD and PLATINUM level, no X-assessed or GREY-assessed materials are allowed to remain in the final BoM. For PLATINUM level, the process chemistry has to be optimised as well.

Optimisation: All hazardous chemicals are identified, all relevant routes of exposure to the biosphere are identified, and there are no relevant high hazards associated with the use of any of the chemicals by the manufacturer of the C2C Certified product.

The optimisation plan should include the following:
• A list of the materials that are X-assessed or GREY-assessed
• An optimisation recommendation from the assessor
• A feasibility assessment (characterising the ease or difficulty of optimisation)
• An action plan, to include an approximate timeline (near-term and long-term) for the implementation, and an estimate of the costs involved

BEST PRACTICE: ENGAGING SUPPLIERS THAT ARE FROM EARLIER STAGES OF THE SUPPLY CHAIN

Translating fuel consumption into carbon footprint requires a conversion rate – the emission factor. Suppliers that are further back in the supply chain will have to be engaged in the process of certification. The garment manufacturer can facilitate this process, as follows:
• Explain the C2C Certified Products Program
• Assure suppliers that their proprietary information will be protected through a non-disclosure agreement (NDA) with the assessor; the specific contents of their product will not be shared – only the overall assessment using the ABC-X methodology
• Explain that participation in the C2C Certified Products Program will help them learn more about their products, and could help them improve their chemistry in ways that better support human and ecological health
• Show them that other major companies are already going through this process, and that participation may give them a competitive advantage; for example, by showing them the Fashion Positive materials collection.
3. LEVELS OF ACHIEVEMENT FOR MATERIAL HEALTH

There are five potential levels of achievement, with each level building on the requirements of the previous one.

<table>
<thead>
<tr>
<th>Level</th>
<th>Requirements</th>
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<tbody>
<tr>
<td>BASIC</td>
<td>No Banned List chemicals; identified biological or technical nutrient metabolism; 100% of ingredients characterised</td>
</tr>
<tr>
<td>BRONZE</td>
<td>75% assessed using ABC-X ratings (100% for biological-nutrient products), and optimisation strategy developed for materials assessed as X</td>
</tr>
<tr>
<td>SILVER</td>
<td>95% assessed using ABC-X ratings; contains no ingredients known or suspected to cause cancer, birth defects, genetic damage or reproductive harm</td>
</tr>
<tr>
<td>GOLD</td>
<td>100% assessed (by weight) using ABC ratings; no X assessed ingredients; meets C2C Certified emissions standards</td>
</tr>
<tr>
<td>PLATINUM</td>
<td>All process chemicals have been assessed, and none has received an X rating</td>
</tr>
</tbody>
</table>

Detailed information on the requirements and instructions can be found in the C2C Certified Product Standard.

4. C2C CERTIFIED MATERIAL HEALTH ASSESSMENT METHODOLOGY

Once the assessor receives and verifies a manufacturer’s BoM, the process of evaluating the chemicals’ risk in terms of hazards and exposure begins. The formula is as follows.

\[ \text{Hazards} \times \text{Exposure} = \text{Risk} \]

IDENTIFYING HAZARDS

The first step is to evaluate the chemical ingredients, independent of any of their applications, against the C2C Certified Products Program’s human and environmental health hazard “endpoints”. The endpoints are objective measurements of a chemical’s properties or of the potential results of exposure; e.g. carcinogenicity, dermal toxicity, or neurotoxicity.

The list of human and environmental health hazard endpoints, and more detail on the Material Assessment Methodology, can be found in the C2C Certified Material Health Assessment Methodology.

CHARACTERISING RISK

Once the hazards are assessed for all the chemicals present in an ingredient, the assessor then looks at the context in which those ingredients are used and the relative routes of human exposure to each ingredient (such as inhalation, skin contact, or biodegradation). From this analysis, the assessor develops an assessment of risk for each chemical present in each material.
MATERIAL HEALTH

Once all the chemical risk assessments have been performed, a final assessment is generated for each material, equating to the result of the worst-performing chemical within the material using the ABC-X rating system below:

Table 3: ABC-X rating methodology

| A | The material is ideal from a C2C Certified perspective for the product in question |
| B | The material largely supports C2C Certified objectives for the product |
| C | Moderately problematic properties of the material, in terms of quality from a C2C Certified perspective, are traced back to the ingredient. The material is still acceptable for use. |
| X | Highly problematic properties of the material, in terms of quality from a C2C Certified perspective, are traced back to the ingredient. The optimisation of the material requires the phasing out this ingredient. |
| GREY | This material cannot be fully assessed owing either to incomplete ingredient formulation or to lack of toxicological information for one or more ingredients |
| BANNED | i.e. banned for use in C2C Certified Products Program |

This material contains one or more chemical ingredients from the Banned List and cannot be used in a certified product

Here is an example of an ABC-X assessment:

- A: Sodium Sulphate (no hazards or risks as used in textiles)
- B: Sodium Carbonate (moderate irritation and inhalation hazard, no risk as used as dye-bath chemical)
- C: Sodium Hydroxide (highly corrosive hazard, only slight risk of exposure in textile processing)
- X: 7-((5-Chloro-2,4-difluoro-6-pyrimidyl)amino)-4-hydroxy-3-((1,5-disulfo-2-naphthyl)azo)-2-naphthalenesulfonic acid, trisodium salt [Reactive Orange 6]--(halogenated organic azo reactive dyestuff that contains both organochlorine and organofluorine and is persistent in the environment)
BEST PRACTICE: BILL OF MATERIALS OPTIMISATION AT COTTON BLOSSOM AND PRATIBHA SYNTEX

Both Cotton Blossom and Pratibha Syntex worked with MBDC, an accredited assessor, to optimise their materials. The first step in the process was for each company to submit an initial BoM to MBDC for assessment. For both companies, many dye and process chemicals were initially assessed GREY, owing to incomplete formulation. In addition, a few X-assessed materials and X-assessed ingredients were identified.

MBDC followed up with the suppliers from earlier stages of the supply chain (Tier-2 suppliers) for more information for the GREY-assessed materials, and in many instances received complete formulations from the initial inquiry. Where the Tier-2 suppliers would not or could not provide complete formulations for their products, MBDC suggested replacement suppliers – suppliers willing to share their formulations and that already had suitable materials assessed as A, B or C. In this way, all GREY-assessed materials were eliminated from both BoMs. Since A, B, and C materials are considered optimised from a C2C Certified perspective, only the X-assessed materials remained for phase-out and substitution.

The majority of X-assessed ingredients were dyes, specifically reactive dyes for cotton or disperse dyes for polyester. The most common issues with the dyes were:

- skin sensitisation (allergic response)
- halogenated organic molecules (potential for persistent, bio-accumulative, and toxic metabolites)
- lack of mutagenicity testing for many dye molecules (dyes should undergo Ames assay at a minimum)

Many of the dyebath and process chemicals revealed high aquatic toxicity and potential for skin irritation. This underscored the importance of workers’ use of appropriate personal protective equipment (PPE) and implementation of measures to prevent molecules with high aquatic toxicity from entering the local waterways.

In this case, both manufacturers have protocols in place to ensure worker safety, and both have completely closed water systems on-site to recycle process effluent. The water-treatment system includes a biological degradation process that allows for microbial digestion of organic effluent chemicals. All problematic molecules – those identified as potentially toxic to fish, aquatic invertebrates, and/or algae – are safely consumed by bacteria on-site, and none of the molecules are released into local waterways.

Cotton Blossom and Pratibha Syntex were able to replace X-assessed dyes with dyes from Dystar that meet the requirements for C2C Certified PLATINUM in Material Health.

Moreover, both manufacturers managed to discontinue dye and process chemicals that contained nonylphenol ethoxylates and organochlorine, replacing them with positively assessed alternative surfactant and scouring/bleaching molecules.

For each company, the resulting BoM was 100% characterised and was stocked entirely of A, B, and C-assessed ingredients; at that point, it was considered optimised. Combined with their effective closed-loop water systems, both Cotton Blossom and Pratibha Syntex achieved PLATINUM level in Material Health.

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5. DESIGN CONSIDERATIONS FOR MATERIAL HEALTH

For textile manufacturers the most important guidelines regarding Material Health criteria are:

A. Choose the right sources of materials
B. Select the right dyes and finishes
C. Avoid incompatible laminations and coatings

A. Choose the right sources of materials
Select sources that will help make a positive impact, and therefore support higher achievement levels in the C2C Certified Products Program.

- Prefer certified organic and sustainable sources (e.g. GOTS certified). Materials from these sources will be (or should be) free of pesticide residues, and that is why they allow higher certification levels in Material Health. In addition, materials derived from sustainable cultivation practices are less likely to have a damaging effect on soil and watershed well-being, worker health, and biodiversity than are materials from more conventional practices.

- Prefer unbleached or chlorine-free fibres. Chlorine bleaching can result in the presence of highly toxic dioxins in fibres, and that will limit the material’s possible certification levels in Material Health. The toxic effects of dioxins include: adverse effects on the reproductive, developmental and immune systems, endocrine disruption and hormone mimicry, mutagenicity and cancer.

- Prefer optimised polyester. Much of the polyester available today uses an antimony trioxide catalyst, which is a suspected human carcinogen, and will limit the material’s certification level in Material Health. Alternative catalysts exist (e.g. titanium-based) that do not have these issues.
B. Select the right dyes and finishes
Design parameters such as colour and softness have a major influence on the subsequent processing required, and hence on the amount of energy and water consumed and chemicals used. For a detailed list of considerations for dyeing, performance additives, finishes and printing, see the section ‘Further Resources: C2C Certified Considerations for Common Apparel Materials’. For a current list of dyes and finishes that have already been assessed, see the Fashion Positive website.

C. Avoid incompatible laminations and coatings
Many textiles are coated or laminated with substances for the sake of adding performance features such as waterproofing, moisture wicking (sweat removal), and odour control. Laminations are especially problematic in that they prevent reutilisation of the product, unless they come from a source compatible with the base fibre. Thus, a polyester film would be suitable for laminating a polyester-fibre fabric but not a cotton fabric. Frequently, it is possible to avoid these additional treatments by taking steps during the design phase to carefully choose the fibre and textile construction. In some cases, materials using gentler approaches, such as waxed cotton, can outperform their conventional synthetic and laminated counterparts.

6. GETTING STARTED

Manufacturers have contributed to high certification levels in Material Health by adopting practices and activities conducive to optimisation. Some activities are fairly simple and can begin right away, but others will require more time and investment.

In the short term
- Assess the baseline:
  - Develop a BoM that is free of Banned List ingredients, and consider including products that have already been assessed (see Fashion Positive Materials Collection)
  - Approach your customers to collaborate with you on a C2C Certified product
- Collaborate:
  - Identify customers that have strong sustainability strategies, tell them the proportion of your current portfolio that would achieve a high C2C certification, and propose a collaboration
  - Invest in prototypes of products with assessed materials, and present these innovations to your customers

In the medium term
- Optimise:
  - For products with a low Material Health score, investigate with your in-house design team how to change the material composition
  - Share with brand partners and suppliers the costs involved in identifying dyes, finishes and process chemicals that will lead to a high certification level in Material Health