Health Care Without Harm

THE ROLE OF CHEMISTRY IN SUSTAINABLE MEDICAL TEXTILES

ABBREVIATIONS USED IN THIS PUBLICATION

Ag	Silver
BAuAt	German federal institute for occupational safety and health
CMR	Carcinogenic, mutagenic and toxic for reproduction
COVID-19	Coronavirus disease 2019
ED	Endocrine disruptors
EEA	European Environment Agency
EFS	European Food Safety Authority
GDP	Gross domestic product
HAI	Healthcare-associated infections
OECD	Organisation for Economic Co-operation and Development
PBT	Persistent, bioaccumulative and toxic
PFAS	Per- and polyfluoroalkyl substances
PFHxS	Perfluorohexane sulfonic acid
PFNA	Perfluorononanoic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctane sulfonate
PPE	Personal protective equipment
PTFE	Polytetrafluoroethylene
PVDF	Polyvinylidene difluoride
SCCS	Scientific Committee on Consumer Safety
SMS	Spunbond Meltblown Spunbond
SMMS	Spunbond Meltblown Meltblown Spunbond
SUPFES project	Substitution in Practice of Prioritized Fluorinated Chemicals to Eliminate Diffuse Sources
TWI	Tolerable weekly intake
vPvB	Very persistent and very bioaccumulative
WHO	World Health Organization

TERMINOLOGY USED IN THIS REPORT

TEXTILE	A finished product
FABRIC	Ingredients or materials that a textile is made of

EXECUTIVE SUMMARY

The production, use, and disposal of medical textiles can cause significant environmental impacts. The use of water, land, chemicals, greenhouse gases and other pollutants are damaging the environment and can also undermine health. The healthcare sector uses a large variety of textile products to provide care. The scope of applications is wide and diverse, ranging from a single thread suture or cleaning wipes to complex composite structures for bone replacement and advanced barrier fabrics used in surgery rooms.

Chemicals are used in medical textile production and can be emitted during their use and disposal (typically through incineration). Substances, such as formaldehyde, azo dyes, heavy metals, and organotin compounds can harm human health and environment. Other hazardous chemicals used in medical textiles include per- and polyfluoroalkyl substances (PFAS), flame-retardants, and antimicrobial (biocidal) substances. Single-use products in particular cause significant environmental harm and there is greater scope for reducing overall toxicity in reusable textiles than in disposable items.

In this report, we present an overview of current materials and chemicals used in the manufacturing process of medical textiles (with a focus on healthcare and hygiene products). The central aim of this report is the importance of both addressing the chemistry of medical textiles, and phasing out of harmful substances contained within them. It is essential to move the healthcare sector towards more sustainable and circular products.

The report also offers a number of key recommendations related to medical textiles for policy makers, manufacturers, and the healthcare sector.

KEY MESSAGES & RECOMMENDATIONS

- **We must further examine medical textiles to determine if their functionality and performance justifies the continued use of hazardous chemicals.**

- **The entire value chain should be able to exchange information on chemicals used in production to improve traceability and further promote sustainable textiles.**

- **Withdrawing or minimising exemptions to use substances of very high concern in medical textile products will decrease the negative environmental and health impact of those products. This will further ensure higher safety and promote the use of non-toxic reusable and recyclable materials.**

- **Policy makers should expand the availability of and reliance upon lifecycle impact assessments of medical textiles and incentivise (re)adopting reusable and recyclable solutions within healthcare.**

- **The healthcare sector has an opportunity to influence markets and lead the transition towards toxics-free reusable textiles, without compromising on the safety and comfort of patients and staff.**

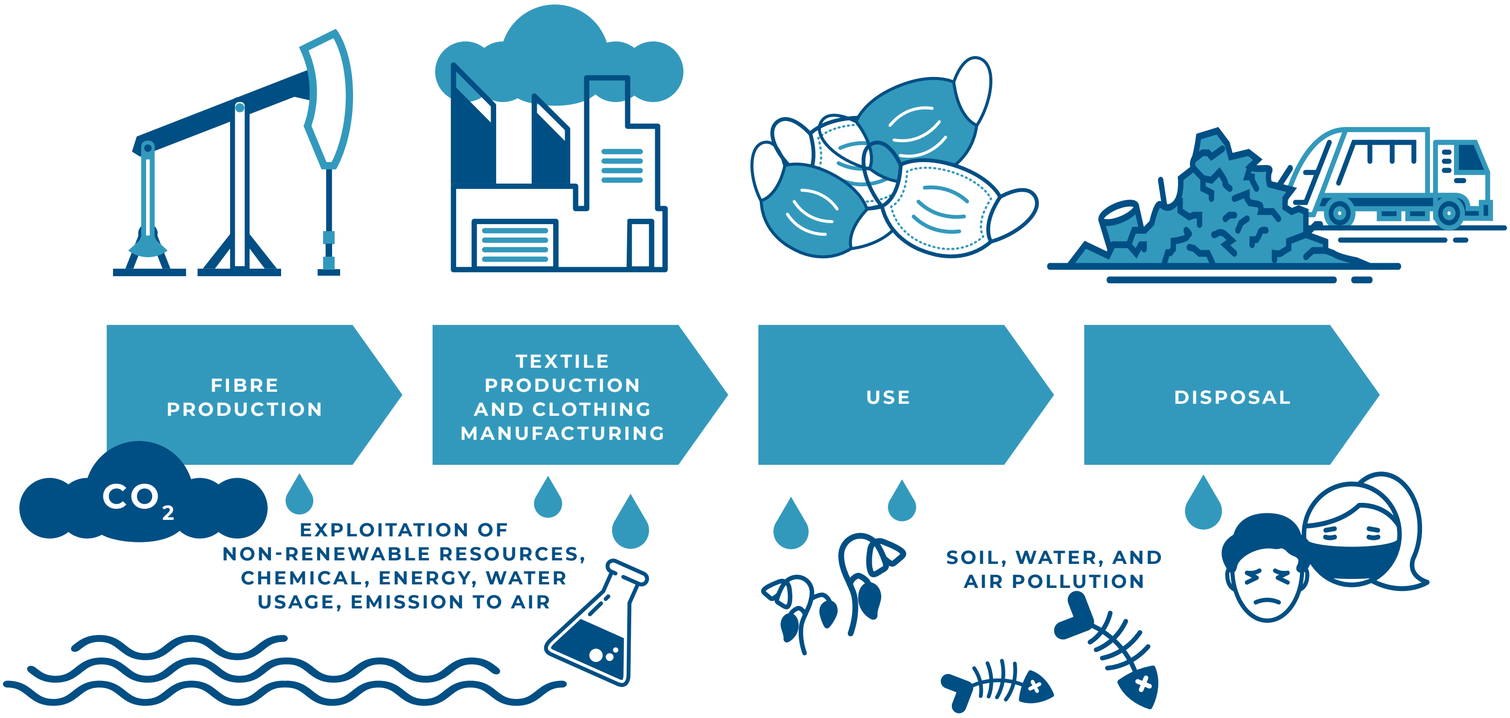
INTRODUCTION

Textiles are fundamental to our society, providing us with clothing, furniture, building materials and life saving devices in the healthcare industry. Yet their production can cause significant environmental, climate, and social impacts through the use of water, land, chemicals, as well as greenhouse gases and other pollutants.[1]

The healthcare sector uses a large variety of textile products. Common high-volume disposable products include baby diapers, feminine hygiene products, adult incontinence products, wound dressings, bandages, gauzes, and medical clothing. There are also many specialised products for use in blood filtration, surgical sutures, and prostheses. The applications of textiles are always under review from both healthcare professionals and industry, in the search for innovations to improve the quality and effectiveness of care.[1a]

Textile technology is under constant development. With a wide range of natural, man-made, and recycled fibres as well as a variety of threads, treatments, and production methods available, there is a near unlimited range of possibilities when producing textiles.[2] New fibres and technologies make it possible to produce cheaper, innovative, and more compatible textile products. Combine this with population growth and an ageing population, the market for medical textiles will potentially be one of the fastest growing technical textiles categories between 2020 and 2025.[3]

The way we currently produce, use, and dispose of medical textiles (particularly hygiene products and medical protective clothing) is highly unsustainable and is causing harm to both our health and our environment. The textile industry has a long and complex supply chain, beginning with agriculture and petrochemical production (for fibre production) through to manufacturing, logistics, and retail. Each step negatively impacts the environment through water, material, chemical, and energy use, as well as polluting soil and wastewater. Many chemicals used in textile production can also harm the health of factory workers and product users. The main methods of disposal for medical textiles are typically incineration or landfill, where harmful pollutants can contaminate air, soil, and water and contribute to climate change.



Single-use products in particular cause significant environmental harm and there is greater scope for reducing overall toxicity in reusable textiles than in disposable items.[4] Increased use of reusable textiles also provides other benefits, including solid waste reduction, cost savings, and improved patient comfort. A switch to reusables also represents a more sustainable alternative to single-use disposable items in healthcare.

In this report, we present a concise overview of the current materials and chemicals used in the manufacturing process of medical textiles (with a focus on healthcare and hygiene products). The central aim of this report is to highlight that addressing the chemistry of medical textiles and phase-out of the harmful substances they contain is essential to move the healthcare sector towards more sustainable development and higher circularity of materials. The report also considers a number of key aspects relating to medical textiles that would benefit from policy and healthcare sector interventions.

WHAT DO WE NEED TO KNOW ABOUT MEDICAL TEXTILES?

WHAT ARE MEDICAL TEXTILES?

“Technical textiles” is an umbrella term for a wide variety of textiles used for function and performance in a broad range of industries, including healthcare, where they play a very important role. Medical textiles (also known as healthcare textiles) represent approximately 20% of the technical textiles sector; this is the largest sub-category and is continually growing.[5] The scope of applications is wide and diverse, ranging from a single thread suture or cleaning wipes to complex composite structures for bone replacement and advanced barrier fabrics used in surgery rooms. Common medical textiles applications include linen, bedding, surgical gowns and aprons, uniforms, caps, masks, and surgical drapes. Medical textiles also include personal protective equipment (PPE) such as respirators, gowns, gloves etc., which have played a pivotal role during the COVID-19 pandemic.

Medical textiles are textile structures designed and produced for use in any of a variety of medical applications, including implantable applications.[5a] The development of medical textiles is typically focused on performance, comfort, and patient safety.

MEDICAL TEXTILES CAN BE GROUPED INTO SEVEN CATEGORIES:[7a]

- **HEALTHCARE AND HYGIENE PRODUCTS**
  e.g. bedding, clothing, surgical gowns, wipes, and other disposable products.
- **EXTRACORPOREAL DEVICES**
  e.g. artificial organs such as kidney, liver, lungs, or pacemakers.
- **IMPLANTABLE MATERIALS**
  e.g. sutures, vascular grafts, scaffolds.
- **NON-IMPLANTABLE MATERIALS**
  e.g. wound dressings, bandages, plasters, pressure garments.
- **INTELLIGENT MEDICAL AND HEALTHCARE TEXTILES**
- **TEXTILES IN HEALTHCARE ENVIRONMENTS**
  e.g. furnishing fabrics, textiles in fixtures and fittings.
- **ENVIRONMENTAL HYGIENE CONTROL COMPONENTS**
  e.g. air filters.

This report provides an overview for healthcare and hygiene products only.

FIBRE, FABRIC, AND TEXTILE PERFORMANCE

Medical textiles can be woven, knitted, braided, or non-woven structures, depending on the application and can include both natural and synthetic fibres. Increasingly, synthetic fibres are predominant in medical textiles – including 100% synthetic fibres such as polyester and polypropylene – whilst cotton is the most popular natural fibre used in such products.[8]

Fibres are typically chosen for their performance and function. Different fibres exhibit different characteristics; some are more durable, easier to wash, or easier to recycle after use, for example. Fibres can also be chosen in conjunction with chemical treatments or coatings that give functional properties such as flame retardancy, water resistance or even antistatic or antibacterial properties to the finished textile.[7] Chemical treatment can significantly improve the fabric and product appearance, wearability, and functionality.

Hygiene is of course a priority consideration for selecting textiles to be used in the health sector, however, user comfort should not be overlooked.[9] User comfort is often assessed by looking at properties such as thermal resistance, water vapour resistance, air permeability, surface friction and roughness, moisture management, or tensile strength. Textile surface properties are also important because of their psychological and physical effects on a person's appreciation of a fabric. The sensations felt when skin is in contact with the textile greatly influences the overall feeling of comfort. Textile characteristics such as fibre type, thread linear density, thread density, weave type, and yarn twist can all affect how a fabric feels to the touch.[10] User testing the comfort of fibres, fabrics, and designs with healthcare staff is recommended for healthcare textiles.[9]

BOX 1

MEDICAL TEXTILES: FORECAST 2020-2025[3]

The market for medical textiles is currently dominated by Europe, followed by North America and Asia-Pacific. Market growth will likely be driven by growing awareness of new wound care technologies, aging and growing diabetic populations, and government funding. North America is predicted to dominate the medical textiles industry due to its rapid expansion in implantable products and health and hygiene products.

MEDICAL PROTECTIVE CLOTHING

Medical protective clothing (including PPE) is essential to safeguard healthcare workers and patients in emergency departments and in wards with highly contagious patients. PPE is designed to prevent the transmission of pathogens contained in the blood and body fluids of patients and minimise the risk of contamination. This barrier property is one of the most essential characteristics for medical PPE such as gowns and coveralls, but resistance to liquids, abrasion, and tearing, as well as comfort must be considered.

GOWNS AND DRAPES

Surgical gowns and drapes can either be made from reusable or single-use materials. In the past, cotton was a common reusable textile, but has now been phased out from operating rooms due to its low resistance to liquid penetration and high porosity. Over the last 15 years, reusable drapes and gowns are increasingly made from synthetic fibres and treatments with desirable properties. This includes composite materials, a combination of woven or knitted fabrics engineered to optimise the performance and characteristics by laminating or coating, such as the trilaminate, a three-layer construction.[11]

Nonwoven fabrics are the essential component of single-use surgical gowns and drapes. They are based on natural and synthetic fibres such as wood pulp, cotton, polyester, or polyolefin.[12] Several nonwoven fibres can provide the softness, breathability, and high level of barrier protection required for PPE and are typically used in a combination of thermally bonded layers. SMS (Spunbond/ Meltblown/Spunbond) or SMMS (Spunbond/ Meltblown/Meltblown/Spunbond) fabrics are commonly used.[12] Fabric and design characteristics, such as strength, pore size, repellency, fit, thermal comfort, and mobility also contribute to textiles' performance.

FACE MASKS

Most surgical facemasks are primarily made from polypropylene and polyethylene, as well as cellulose, polyolefin, and felt.[12] Surgical facemasks typically comprise three layers of polypropylene. The outermost spunbond layer (typically blue) is waterproof and repels fluids, the middle meltblown layer acts as the filter, preventing particles or pathogens (within a specified size range) from penetrating in either direction. The innermost spunbond layer is made of absorbent materials to trap liquids from the user, i.e. mucosalivary droplets. This inner layer also absorbs moisture from exhaled air, thereby improving comfort.[13] Used in combination these materials create a strong product that can also offer an effective barrier to fluids and particles.

Surgical facemasks, previously only used by the healthcare sector, are now being used globally by large sections of the public amidst infection concerns surrounding COVID-19. With supply chains stretched, other materials have been used to replace the meltblown polypropylene that is typically used in N95, FFP2, FFP3, and surgical masks. Solvay's solutions, for example, include materials using PFAS for their production: Solef® PVDF and Algoflon® PTFE.[14]

IDENTIFYING HAZARDOUS CHEMICALS IN MEDICAL TEXTILES

Approximately 3,500 substances have been identified in textile production, of which 750 have been classified as hazardous for human health and 440 as hazardous for the environment.[1]

PROBLEMATIC CHEMICALS AND CHEMICAL-RELATED ISSUES PER PRODUCTION STAGE[15]

RAW MATERIALS	• Pesticides • Fertilisers • Crude oil • Fracking agents
FIBRE PRODUCTION	• Solvents • Carbon disulfide • Surfactants • Monomers • Catalysts
YARN SPINNING	• Spinning oils
FABRIC MANUFACTURING	• Needle oils • Sizing agents
WET TREATMENT	• Detergents • Lubricant • Stabilisers • Bleach • Dyestuff • Salts • Softeners • Finishing agents
DRYING/ FINISHING	• Air emissions • Prints • Finishing agents
GARMENT MAKING	• Stain removal • Spray bleaching
TRANSPORT	• Biocides • Container gas • Fuel combustion

The legal limit for the use of these chemicals may vary between countries, and product manufacturers can source textiles from anywhere in the world, yielding both benefits and disadvantages. Compliance of imported products is often an issue; recent investigations have shown that imported disposable face masks in the UK and FFP2 face masks in Germany contained harmful pollutants including lead, antimony, and cadmium.[16] [17] While individual concentrations of these substances were relatively low, the total amount was considerable.

Chemical finishes/coatings can be durable or non-durable, and different chemicals will bind at different strengths to different fibres.

CHEMICALS FOUND IN TEXTILES FINISHES[18]

CHEMICALS	FUNCTION (CLAIMED BY MANUFACTURERS)
Formaldehyde or formaldehyde resins	• Easy care finish (water-, oil-, stain-, and wrinkle resistance)
Formaldehyde, citric acid	• Crease resistant finish
Oxy-ethylated polyamides	• Hydrophilic finishes
Silicone, poly ammonium quaternary salts	• Anti-static finishes
Silica gel	• Non-slip finishes
Azo dyes, disperse dyes	• Dyeing
Per- and polyfluoroalkyl substances (pfas)	• Repelling both water and oil
Brominated flame retardants, chlorinated flame retardants, phosphorus-containing flame retardants	• Fire resistant finishes
Phenols, quaternary ammonium compounds, (nano)silver, copper, zinc	• Antimicrobial finish

These chemicals are commonly used in textiles, but there are further substances used for functions such as plasticity, water resistance, and flame retardancy. Textiles can also contain plasticisers, allergens, and some (unintentional) impurities.

CHEMICALS OF EMERGING CONCERN

USED IN MEDICAL TEXTILE PRODUCTION

We need to focus on reducing entire classes of problematic chemicals, rather than phasing out individual chemicals one at a time. Such an approach will help develop coordinated strategies for reducing the production and use of chemicals of concern and prevent regrettable substitutions.

PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS)

PFAS is a large family of thousands of organic synthetic chemicals, with the carbon-fluorine bond being the cornerstone chemical structure for the entire class. The PFAS group also includes polymers, for example fluoropolymers, perfluoropolyethers, and side-chain fluorinated polymers. The OECD has published a clear explanation of the different groups of PFAS.[19]

A report prepared for the European Commission on the use of PFAS highlighted that water, oil, and dirt repellence are the primary functions of PFAS in textiles. Other functional properties, such as thermal resistance and breathability, were also mentioned by industry stakeholders.[6] The ability of PFAS to efficiently repel both water and oil is seen as a key physical property by industry stakeholders for high performance textiles, especially PPE and non-clothing technical textiles, which have a wide range of applications. For example, PFAS are used in medical applications to repel a range of fluids (including bodily fluids such as blood).[5]

Polytetrafluoroethylene (PTFE) and short-chain fluorinated polymers are the most common PFAS chemicals used in textiles. They are typically used in a liquid repellent finishing which can be found in single-use surgical gowns and drapes, for example. The finishing can also be combined with a PTFE-membrane in products such as ambulance jackets.

FLAME-RETARDANTS

Healthcare settings often contain a number of fire hazards with sources of heat, fuel and oxygen. The natural and synthetic fibres of textiles are typically flammable and can pose potential risks to the wearer due to the speed and intensity of flame spreading.

To make combustible materials more resistant to fire or causes of fire, flame-retardant chemicals or materials are often added. Flame-retardants decrease momentum of combustion and stop fire from spreading to other items. Flame-retardants are used in healthcare settings in a range of textile applications such as beds, curtains, drapes, upholstery, wall coverings etc.[20]

FLAME-RETARDANTS ARE CLASSIFIED ACCORDING TO THEIR COMPOUNDS:[21]

1. Halogens (Bromine and Chlorine) flame retardants compounds
2. Nitrogen flame-retardants compounds
3. Minerals (based on aluminium and magnesium) based flame-retardants compounds
4. Phosphorus based flame-retardants compounds
5. Other various flame-retardants (e.g. boron composites, antimony trioxide, zinc composites).

ANTIMICROBIALS
(BIOCIDAL SUBSTANCES)

Antimicrobial molecules include antibiotics and biocides with a bactericidal or bacteriostatic effect. Active biocides or biocidal substances are defined as substances that have an action on or against harmful organisms, according to the EU Biocidal Products Regulation.[22]

Textiles are often treated with antimicrobials to limit or reduce the growth of some microorganisms. These bacteriostatic or fungistatic treatments protect the textile from odour and degradation. Antimicrobials may also be used in textiles to kill microorganisms (bactericide or fungicide treatments).

Antimicrobial effects within textiles are created through the application of specific chemicals during the finishing stage or incorporating these substances into fibres when transforming them into fabric.[23]

ANTIMICROBIALS IN TEXTILES CAN BE DIVIDED INTO THREE MAJOR GROUPS:

- Antimicrobial polymers
- Metal ions/metal oxides (such as silver, copper and zinc)
- Emerging functional nanomaterials.[24]

Commonly used antimicrobial agents include metallic salts, quaternary ammonium compounds, triclosan, N-halamines, graphene oxide, polypyrrole, chitosan, and flavonoids.[25] Silver is, however, the most widely used both in general and in medical textiles.

BOX 2

NANOSILVER IN HEALTHCARE TEXTILES

Silver exerts strong biocidal effects on many pathogenic bacteria. When metallic silver reacts with moisture on skin or wound fluids, silver ions are released, damaging bacterial RNA and DNA, thus inhibiting replication.

Nanosized inorganic particles possess a high surface area/volume ratio and display unique physical and chemical properties. Nanosilver can be incorporated into textiles for wound care management or used in surgical gowns, face masks, and drapes. Urinary and vascular catheters and other invasive devices such as bone prostheses, cardiac implants, and needles used in ocular surgery can be impregnated with silver compounds to reduce the risk of infection.[26] A study led by ETH Zurich (Swiss Federal Institute of Technology) reported that the initial concentrations of silver in textiles ranged between 1.5 - 2,925 mg/kg.[27]

During the COVID-19 pandemic, antimicrobial impregnated products have been offered to reduce the burden of coronaviruses. Companies are not only marketing these products to hospitals, but directly to consumers (see Box 3).[28 29]

Further measures are necessary to ensure that biocide treatment of an article is fit for purpose.[30] This should be done according to recognised and harmonised test criteria appropriate to products' purpose and use conditions. The efficacy of biocidal treatment in products cannot be assumed based on the known efficacy/ general biocidal properties of the active substance alone – proof is needed that treated products can provide a sufficient effect on one or several target organism groups.

The fundamental question is: how helpful is treating surfaces with biocides in the fight against microorganisms? Health Care Without Harm's 2016 report *Antimicrobials in Hospital Furnishings: Do They Help Reduce Healthcare-Associated Infections?* found very little evidence that adding antimicrobials to textiles helped to reduce healthcare-associated infections (HAI).[31] Currently, there is still insufficient evidence that the presence of antimicrobial agents in clothing, furniture, or plastic adds any value to routine cleaning and disinfection.

BOX 3

NANOMATERIALS USED AS ANTIMICROBIAL AGENTS IN REUSABLE FACE MASKS[i]

The market already proposes different reusable face masks made with nanoparticle fabric which offer adequate protection and bactericidal activity.

Masks using sono-finishing technology provide active protection against viruses, bacteria and fungi with >99% efficacy. Textiles are treated with zinc oxide nanoparticles and remain effective for the duration of 55 washes.[32]

The face masks containing nanosilver strongly inhibit bacterial growth through suppression of respiratory enzymes and electron transport components and through interference with DNA functions, with no function loss after washing 260 times in standard water.[33]

Other masks using thermaissance technology are made from a fabric that inactivates coronavirus in less than an hour. It also kills various other multi-drug resistant organisms.[34] The fabrics are based on nanotechnology, last for more than 60 industrial washes and do not contain any plastics. The company incorporated nanometre-sized sheets of molybdenum sulphide into the fabric, the sharp edges and corners of which act as tiny knives that pierce bacterial and viral membranes, killing them.[35]

i HCWH Europe used open sources to present the claims of the manufacturers and is not responsible for any incorrect information related to those products. All products listed here can be bought online and imported in European countries at time of writing.

THE HEALTH AND ENVIRONMENTAL IMPACT OF MEDICAL TEXTILES

It is estimated that 20% of global water pollution is caused by dyeing and finishing textile products, affecting the health of workers and local communities.[1] Workers are exposed to chemical substances during manufacturing,[36] and residue of hazardous chemicals used during production can remain in textiles posing health risks for users.[9] Any health implications, including allergic reactions, are generally a response to fibre treatments, such as dyeing and other chemical finishes, rather than the textile itself.

PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS)

PFAS are extremely persistent, often referred to as 'forever chemicals'. They do not break down easily and can accumulate in our bodies and the environment. PFAS chemicals can also be highly mobile; once released into the environment, they can spread quickly. Major routes of human exposure are contaminated food, water, air, consumer products, and household dust. The leaching of PFAS out of textiles might not only have an environmental impact; PFAS in clothing may also form a direct exposure route to humans, since there is dermal contact with the textiles. It has been shown for example that PFOA can penetrate human skin.[37,38]

Health effects associated with PFAS include cancer, hormone disruption, liver and kidney damage, developmental and reproductive harm, changes in serum lipid levels, and immune system toxicity, with some of these effects occurring even at extremely low levels of exposure.[39]

The European Food Safety Authority (EFSA) has recently set a new safety threshold for the main perfluoroalkyl substances that accumulate in the body.[39] The four PFAS that EFSA's assessment focused on are perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), perfluorononanoic acid (PFNA), and perfluorohexane sulfonic acid (PFHxS). The threshold – a group tolerable weekly intake (TWI) of 4.4 ng per kg of body weight – is part of a scientific opinion on the risks to human health from the presence of these substances in food. Experts considered the decreased response of the immune system to vaccination to be the most critical human health effect when determining the TWI, and worryingly concluded that a considerable proportion of the European population is expected to exceed the TWI. Young children are the most exposed population groups, and exposure during pregnancy and breastfeeding is the main contributor to PFAS levels in infants. The International Federation of Gynecology and Obstetrics recently issued an opinion calling for PFAS chemicals to be restricted around the globe.[40]

There are also further concerns regarding the safe disposal of fluoropolymers and their associated products and articles at the end of their lifecycle. Whilst some industrial fluoropolymers are recycled and reused, there are limited options for consumer articles. There is no scientific rationale that fluoropolymers are a low concern for environmental and human health.[41] They are extremely persistent and are a source for human exposure to PFAS. The associated emissions from production and use should be restricted to essential use only.[42]

FLAME-RETARDANTS

A key issue of flame-retardants is that they are harmful to human health and toxic to wildlife. They can leak from products into dust and air where they may persist in the atmosphere and accumulate in living organisms.[21] There is growing evidence that many flame-retardant chemicals can affect the endocrine, immune, reproductive, and nervous systems. Some animal studies have shown that long-term exposure to flame-retardants can lead to cancers. Children may be particularly vulnerable to the toxic effects of these chemicals, because their brain and other organs are still developing. Researchers have found that children have higher concentrations of flame-retardants in their bodies than adults.[43]

ANTIMICROBIALS

Risk from antimicrobial textiles are evaluated via acute and chronic toxicity, skin sensitisation and irritation, and the disturbance of skin ecology.[44] Silver may unintentionally interact with so-called "good" bacteria such as skin flora and weaken the natural skin defence barrier. The extent to which humans could be exposed to antimicrobial textiles is usually influenced by the action of the antimicrobial agent (diffusion or contact), its concentration in the textile, the exposure routes, and the frequency of use.[45]

The potential unintended consequences of biocidal substances have simply not been explored fully, even for the most frequently used antimicrobials such as (nano)silver which is used as an antimicrobial in toothpastes and skincare products. The Scientific Committee on Consumer Safety's latest opinion on nanosilver found in vitro genotoxicity "which cannot be ignored". The committee has also expressed concerns over combined exposure levels from different sources, including clothing.[45] Human skin is exposed to nanosilver via various medical applications containing nanosilver. Some medical applications such as coated catheters and orthopaedic implants, represent more invasive routes of exposure.[46] Most of the time these exposures are local, but catheters, for example, can lead to intravenous, and thus systemic exposure. A possibility of exposure to nanosilver via skin and inhalation has been recorded for wound dressings and breathing masks, respectively.[46]

The important issue related to antimicrobials in textiles is that they often suffer from poor durability due to the leaching. This can readily occur during use and laundering when biocide is incorporated into textile fibres.[45] As well as impacting the textile's functionality and performance, leaching of antimicrobials from the fabrics causes potential exposure for users' skin and contamination of the environment.

Biocide use and emissions to the environment can lead to the emergence of biocide resistance, and more importantly, potential cross-resistance to antibiotics.[47]

The World Health Organization (WHO) highlights the serious risks of excessive biocide use when tackling antimicrobial resistance during the COVID-19 pandemic.[48]

The rapidly increasing use (driven by COVID-19) and commercialisation of antimicrobial-impregnated textile products, and face masks in particular, must be critically reassessed for both safety and necessity. Earlier this year, the Belgian government recalled the textile face masks which had been distributed free of charge through pharmacists since June 2020, after finding that they may contain nanoparticles of silver and titanium dioxide, which when inhaled could damage the respiratory tract.[49] In a similar move, French public health authorities recently recalled FFP2 masks containing graphene (labelled as "Biomass Graphene"), particularly from hospitals.[50] This ban followed a decision of Canadian authorities banning the use and sale of masks containing graphene or biomass graphene due to concerns about their potential inhalation and negative health effects.[51]

CIRCULAR TEXTILES ECONOMY

The European Environment Agency's briefing, *Textiles in Europe's circular economy*, provides an EU perspective of the environmental and climate pressures from textile production and consumption. The briefing discusses how circular business models and regulation can help move us towards a circular textiles economy.[1] To produce fibres and fabrics, today's textile industry largely relies on non-renewable resources, such as oil to produce synthetic fibres, fertilisers to grow cotton, and chemicals to produce dye, and finish fabrics. Washing releases chemicals and microplastics into household wastewater. It is estimated that approximately half a million tonnes of plastic microfibres are released into the ocean annually from washing plastic-based textiles.[1]

Disposal of used textiles is another source of contamination. For example, when fluoropolymers are incinerated they can break down into perfluorinated compounds including PFOA.[52]

Choosing the right fibre can deliver environmental benefits in a number of ways. As highlighted in the guide, *Greener textiles in hospitals*, different fibres have different environmental profiles during production.[9] The environmental impacts of multi-use healthcare textiles will be the highest during the use phase, while for single use the impacts will be weighted towards the production and disposal phase.

During the COVID-19 pandemic the significant rise in single-use plastic-based medical personal protection equipment, such as masks and gloves, became an increasing cause of pollution (see Box 4).[53] These products are typically sent to landfill or incinerated, therefore a significant amount of fibres and microfibres find their way into the natural environment. This situation worsened when the use of surgical masks and gloves by the general public was recommended or even required across Europe.[53]

BOX 4

IMPACT OF FACE MASKS AND GLOVES DURING PANDEMIC

Net imports of PPE to the EU-27 during the COVID-19 pandemic totalled 170,000 tonnes for face masks and 105,000 tonnes for plastic and rubber gloves. Between April and September 2020, the production, transport, and waste treatment of face masks is estimated to have resulted in an additional 2.4-5.7 million tonnes of CO_2 being emitted, with a further 1.5 million tonnes from single-use gloves.[53]

Lifecycle assessments of the environmental impacts of PPE distributed to health and social care in England during the first six months of the COVID-19 pandemic estimate a carbon footprint of 106,478 tonnes. The greatest source of this increased CO_2 is attributed to gloves, aprons, face shields, and Type IIR surgical masks. Per day this equates to a mean of 591 tonnes CO_2e, equivalent to 27,000 times the average citizen's carbon footprint, or 244 return flights from London to New York.[54]

The estimated impact of the increased emissions is 239 disability adjusted life years, a loss of 0.47 species/year, and resource depletion valued at a loss of £9.3 million.

The environmental effects of littering still need to be better understood, as littered masks do not only harm animals through entanglement or ingestion, but also represent an additional source of microplastic or nanoplastic pollution.

ALTERNATIVES HOW TO IDENTIFY AND ASSESS THEM

The first step in identifying any alternative is understanding how chemical substances affect the critical performance of a medical textile as well as the function of the product and the related interaction with the user.

Unfortunately, due to a lack of manufacturer transparency, it is difficult to accurately assess the nature and concentration levels of chemical substances contained in medical textiles. Often, knowledge regarding hazardous substances becomes available to the public only when new legislation is under preparation and industry representatives request derogations for the use of certain chemicals, albeit without providing information on their scope and on the lack of alternatives. Therefore, to support more informed policy making, there is an urgent need to know more about harmful substances contained in medical textiles as well as the regulatory and performance requirements for medical fabrics. This will in turn provide an understanding of how certain chemicals fulfill essential textile functions. The concept of essential vs. non-essential use[55] could be adopted for determining when uses of such chemicals are not necessary (and can therefore be phased out), as well as the precise requirements for a substitute.

Alternative medical textiles need to be chosen according to specific requirements. Repellency to bodily fluids coupled with antimicrobial action, for example, is necessary for medical protective clothing to avoid the transmission of diseases.

The textile industry is phasing-out long-chained PFASs and replacing them with alternative chemicals that also deliver the desired water repellency effect. These alternatives can be divided into three main groups: fluorocarbon-based, silicon-based, and hydrocarbon-based polymers. Alternatives from all three main groups, were assessed on their functionality and their impact on the environment in comparison with PFAS chemicals.[37 56] It was concluded that the currently available non-fluorinated alternatives do not provide sufficient liquid repellency for medical textiles.

When a high performance level is required, alternatives offering a lower level of performance/protection could lead to increased risks for healthcare providers.[5] According to manufacturers and industry stakeholders, developing alternatives for such application areas is challenging because switching to alternatives takes a long time for both practical and regulatory reasons. One industry stakeholder suggested that a transition period of 15 years would be required for the healthcare sector.[5] Another example where the essential vs. non-essential use principle should be used is application of antimicrobials used in textiles. The best alternative would be to use antimicrobials only when truly necessary. For example, chemical treatment with biocidal substances is not one of the technical requirements for protective fabric masks.

Some European authorities are already applying the precautionary principle in case of antimicrobials-containing face masks. The benefit of a virucidal/antiviral treatment of masks has not yet been proven, nor has their safety been checked by the authorities. The German Federal Institute for Occupational Safety and Health therefore refrains from recommending the use of such masks.[57] French public health authorities now require companies manufacturing/selling surgical masks[58] to prove any product claims before placing products on the market.
Any claimed benefits linked to the use of a substance or of a biocidal material must be demonstrated in comparison with untreated masks.

The ongoing studies need to assess the risks associated with the presence of a biocidal substance or material, and should consider:

- The potential release of particles or volatile substances.
- The risks of inhaling or ingesting these particles or volatile substances.
- Exposure to particles or volatile substances from daily and long-term use of the mask.
- The demonstration of the biocompatibility of the mask as well as the risks of skin irritation and hypersensitivity reactions.
- Where applicable, the particular risk of exposure to nanoparticles.

Such a strategy should be applied to all biocide-treated textile products.

New developments in fire retardant finishing are focussed on low cost, commercial, and eco-friendly alternatives.[59] [60] Though many of these appear promising, their economic feasibility and wash stability must be established for different end uses. The need of future direction of research required in this field is identified.[60]

It should not be forgotten that fabric and design characteristics can also significantly contribute to product performance.[61] Important fabric characteristics that impact barrier properties include pore and surface characteristics and the amount of twist used for the yarns. Pore size, geometry, and distribution characteristics change with the fabric construction types (woven vs. nonwoven). The random orientation of the fibres in nonwoven fabrics, for example, successfully reduces liquid transmission.[61] Only where the barrier properties of material (additional layers of material) may not be adequate for the particular application, should additional coating, laminates, or reinforcements be added.

THE WAY FORWARD

The human health and environmental impact of chemical production, the application of chemicals in medical textile materials, and the subsequent use and disposal of such products, is a growing global concern. Hazardous substances such as carcinogenic, mutagenic and toxic for reproduction (CMR), endocrine disruptors (ED), persistent, bioaccumulative and toxic (PBT), and very persistent and very bioaccumulative (vPvB), should not be released into the environment during production, use, and disposal of textiles.

To support a phase-out of hazardous chemicals in medical textiles we need to firstly understand which chemicals are present in textiles. We then need to assess the hazards associated with the chemical and determine whether it is necessary for the textile's functionality and performance.

With 2.4 million hospital beds available across the EU-27, the healthcare sector accounts for approximately half of public spending in the EU and 10% of annual EU GDP.[62] The European healthcare sector can therefore play a significant role in influencing markets and lead the transition towards non-toxic circular textiles, without compromising on the safety and comfort of patients and staff. It is possible to respect these two issues while also reducing environmental impacts.

We recommend that healthcare providers demand detailed evidence from suppliers on chemicals used in textile products before making any purchasing decisions. They should also consider whether these products carry any associated risks related to presence of hazardous chemical(s), which can outweigh any of the claimed benefits for patient and staff safety.

Whenever possible, textile certification programmes should be used for medical textiles. Such certification can cover a range of issues, from adherence to chemical limit levels to examination of the supply chain to ensure ethical and sustainable production.

Hospitals consume enormous amounts of disposable nonwoven products, such as sheets, wipes, and protective clothing. One critical way to reduce environmental impact, often overlooked in healthcare, is to extend the use life of textile products as far as possible. In fact, this also offers great potential to make financial gains. Any hospital textile recycling strategy should be careful not to compromise product's durability - a longer lifetime gives far greater environmental benefits than recycling.

If hospital textiles were reused more often and made of recycled materials, their chemical footprint would be significantly reduced.[63] Reusable medical apparel could reduce natural resource energy consumption by 64%, greenhouse gas emissions by 66%, blue water consumption by 83%, and solid waste generation by 84%.[64] Importantly, case studies demonstrate that a transition to reusable isolation gowns can also deliver significant cost savings, while preserving the safety of healthcare workers.[65]

There are a number of on-going pilot projects focusing on increasing circularity of medical textiles; shifting to multi-use gowns and face masks or developing processes for using recycled materials in hospital textiles.[66] The UK government's PPE Strategy for healthcare and social sector aims to move away from disposable

PPE by default and assess new types of PPE that are designed for reuse from the outset.[67]

One of the worries related with multi-use textiles is the release of synthetic fibres leading to microplastic pollution. Currently, this issue is tackled through the use of special wastewater filters in laundries. A 2018 report *Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products*, concluded that as more textiles samples are tested for fibre release during washing, there is a need for standardisation.[68] Once such a measurement protocol is developed and approved, it should amend both the EU Ecolabel criteria for Textile Products and Green Public Procurement criteria for Textile Products and Services, to include only synthetic textiles that exhibit the lowest rate of loss.

It is vital to achieve effective chemical management throughout the whole textile value chain and go beyond simply looking at what is in the final product. The medical textile industry should therefore provide traceability in its value chain, allowing buyers to make more informed choices. The medical textile industry has an opportunity to introduce new types of environmentally sustainable medical protective clothing that will help us prepare for future crises. Washable and reusable products reduce resources-use and medical waste. In a circular economy, waste is designed-out by intention; landfill, incineration and waste-to-energy are therefore not part of a circular approach.[69]

RECOMMENDATIONS

The adoption of a circular economy model of non-toxic medical textiles, where pollution is reduced, materials are reused and recycled, and no waste is left behind, requires a strategy and associated actions to speed up this transition.

RECOMMENDATIONS FOR POLICY MAKERS

- Professional and technical textiles linked to PPE and medical textiles need further examination to determine if their functionality and performance justifies the continued use of hazardous chemicals.

- Withdraw exemptions for substances of very high concern in medical textile products. This will decrease the environmental impact of those products, ensure higher safety, and promote the use of non-toxic reusable and recyclable materials.

- Mandatory requirements for textiles should cover assessment of microplastic releases from textiles. Microplastic releases and textile shedding consideration should be incorporated in all main instruments tackling textile products to prevent this form of plastic pollution.

- Incentivise (re)adopting reusable and recyclable solutions within healthcare. In the EU this could be achieved via the upcoming strategy for sustainable textiles.[70]

- Future strategies for medical textiles should support more sustainable production and consumption, e.g. incentivising 'product as a service' and other sustainable business models. Strategies should also investigate how to sort technical textile waste and disposal treatments. The role of extended producer responsibility in promoting sustainable textiles and treatment of textile waste in accordance with the waste hierarchy should be considered.

- Policy makers and national authorities should expand the availability of lifecycle impact assessments of medical textiles, establishing a common methodology. They should also support increased transparency and access to information on product specifications, chemical inputs, materials used, and production practices. This would support the incorporation of social, environmental, and health considerations into procurement and overcome challenges in identifying and comparing low-carbon, sustainable products.

- To stimulate markets for climate-neutral and circular products and services, policy makers and national authorities should increase awareness and skills of procurement professionals to strengthen the capacity for sustainable public procurement, Green Public Procurement criteria, and eco-labelling. Mandatory standardised labelling and claims on sustainable and circular textiles must be introduced to ensure environmental claims are relevant and reliable.

RECOMMENDATIONS FOR MANUFACTURERS

- The entire value chain should be able to exchange information on chemicals used at every step of production, in full respect of business confidentiality and of other business needs.

- To promote truly sustainable textiles, traceability should enable the exchange of data not only on chemicals, but also product origins, end-of-life options, raw materials, processes/manufacturing, logistics and working conditions, social and environmental conducts of businesses, legislation compliance, standards, and labels.

- Healthcare textile production and related services, e.g. decontamination, washing, repairing could bring sustainable jobs. Industry should therefore stimulate creation of local or regional manufacturing, sourcing, and distribution facilities for medical textiles/PPE.

RECOMMENDATIONS FOR THE HEALTHCARE SECTOR

- The healthcare sector has an opportunity to influence market supply and demand and lead the transition towards toxics-free textiles, without compromising on the safety and comfort of patients and staff.

- The first step towards improvement should be a clear demand from the healthcare sector for manufacturers to publicly disclose information on all harmful substances used in the production of medical textiles.

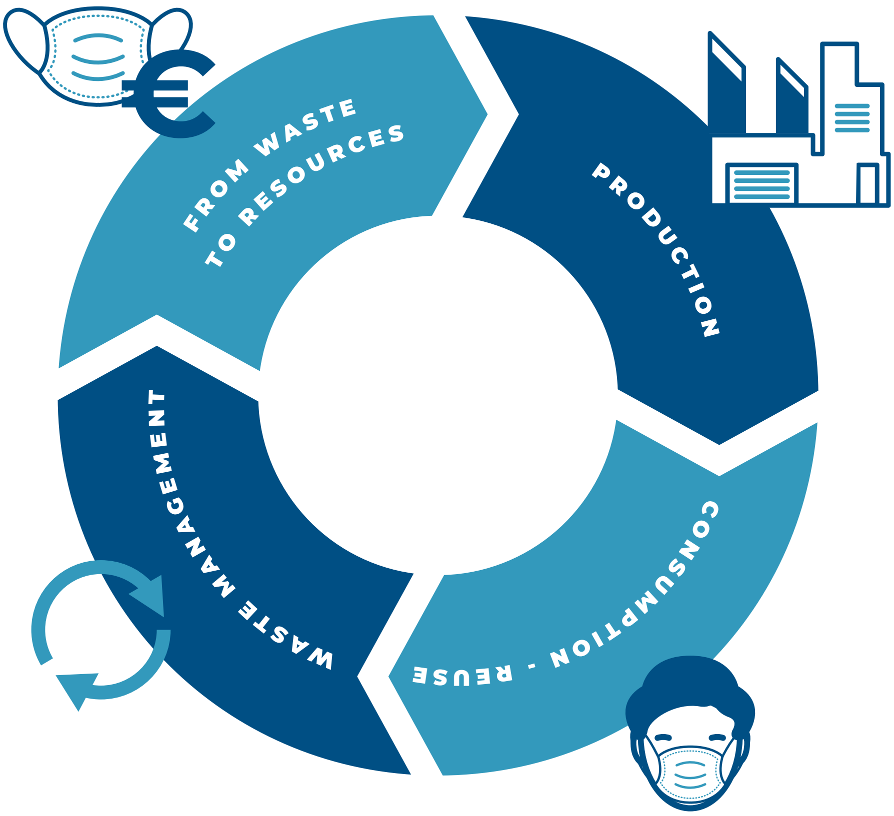
- When healthcare providers consider shifting to new products, there is a significant opportunity to carefully consider the materials and chemical substances used in their production and treatment. The healthcare sector can support toxic-free and sustainable solutions with their purchasing decisions.

- Healthcare practitioners and hospital managers need to recognise the growing environmental problems linked to single-use items and take steps to adopt reusable textiles. Procurers can use their influence to demand toxic-free reusable alternatives.

- The healthcare sector should actively support education of its staff to increase knowledge about the environmental impact of medical textiles. The sector can stimulate the use of more sustainable circular products and positive behavioural change towards appropriate use of textile products, (e.g. reduce unnecessary use).

“Scaling up circularity and sustainable consumption and production is essential to address the three planetary crises we are facing: the climate crisis, the biodiversity and nature crisis, and pollution and waste crisis. The calls-to-action should inspire and redirect the efforts of government, business and finance, and consumers, because at the end of the day, each and every one of us has the power and responsibility to contribute to the transition.”

INGER ANDERSEN
Executive Director - UN Environment Programme.[71]



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