DECEMBER 2021

Toxics Link
for a toxics-free world

AN OVERVIEW OF

TOXIC CHEMICALS IN TEXTILES

About Toxics Link

Set up in 1996, Toxics Link is an Indian environmental research and advocacy organization engaged in disseminating information to help strengthen the campaign against toxics pollution, provide cleaner alternatives and bring together groups and people affected by the problem. Toxics Link's Mission Statement is: "Working together for environmental justice and freedom from toxics."

We have taken it upon ourselves to collect and share both information about the sources and the dangers of toxins in our environment and bodies, and information about clean and sustainable alternatives for India and the rest of the world. The unique expertise of the organization lies in the areas of hazardous, medical, and municipal waste, international waste trade, and the emerging issues of pesticides, Persistent Organic Pollutants (POPs), hazardous heavy metal contamination, etc. from the environment and public health point of view. We have successfully implemented various best practices and have brought in policy changes in the aforementioned areas apart from creating awareness among several stakeholder groups.

Report and Study by:
Piyush Mohapatra (piyush@toxicslink.org)
Dr. Omkar Gaonkar (omkar@toxicslink.org)

Toxics Link
H2 (Ground Floor), Jungpura Extension
New Delhi-110014, India
Phone: +91-11-24328006, 24320711
Fax: +91-11-24321747
www.toxicslink.org

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Foreword

The textile industry has grown multifold during the past few decades. Furthermore, a paradigm shift is being observed across the industry, from the traditional, natural fabrics and dyes, to the synthetic chemical-based ingredients. As a result, the demand and consumption of chemicals in the textile industry is also increasing. Textile chemicals are utilized for a variety of purposes; to determine the effectiveness of textile production and the quality of finished products. The textile production started in the west but gradually moved to low-cost developing countries, such as India, China, Bangladesh, Indonesia, etc. However, the environmental and social impacts associated with the textile sector are significant and therefore of an increasing concern to the global community. Such impacts are intense in these emerging and developing countries. Many chemicals used in textile production have adverse health and environmental impacts. It is estimated that if we eliminate the present negative health impacts emanating from poor chemicals management in the textile industry, it would have an economic benefit of 8 billion US$ in 2030.

Under both, SAICM and the Stockholm Convention on Persistent Organic Pollutants (POPs), many textile chemicals, such as per- and polyfluoroalkyl substances (PFAS), decaBDE, etc. have been increasingly gaining international attention in the recent years. Hazardous chemicals are found in textile products regularly, which have also led to an increased awareness of the health and environmental impacts caused by hazardous chemicals in textile-producing countries. Since 2009, chemicals in products have been identified as an Emerging Policy Issue by SAICM, which has enhanced the efforts to gather and exchange information on toxic chemicals and support the transition to safer alternatives.

In this context, this report provides a preliminary understanding of the major chemicals of concern used in the textile industry, and their health and environmental impacts. This study highlights the existing global regulations governing these chemicals. The report further identifies the need to manage chemicals for an improved public health and environmental protection in the textile sector. With this study, we intend to initiate a discussion on reducing the net chemical consumption in the textile sector, and also reducing the net discharge to the environment.

While examining the literature for this study, we came across two significant gaps on the chemicals in textiles. Firstly, most of the surveys on chemicals in textile products are conducted in developed countries such as the USA, Australia, the UK, Denmark, and other countries across Europe. But, research in the context of emerging economies like India is a matter that remains highly unexplored. Secondly, previous studies have reported that India has focused largely upon technological as well as economic aspects of the textile industry. We hardly find any study capturing the hazardous chemicals in the textile value chain. A review of the global regulatory requirements highlights that there are stringent regulations concerning most of these chemicals only in the developed world, especially in the EU; whereas, regulations on some of the chemicals either do not exist or are less stringent in the developing or emerging economies. The toxicological information on these chemicals also does not exist.

The textile industry, with an estimated value of 1.3 trillion USD, is one of the largest industries in the world and employs more than 300 million people along the global value chain.

01
Introduction

The textile industry, with an estimated value of 1.3 trillion USD, is one of the largest industries in the world and employs more than 300 million people along the global value chain.[1] All the processes involved in converting the raw materials, such as cotton or wool into a finished product, namely, developing, producing, manufacturing, and distributing textiles, are included in the textile industry (Fig. 1). This industry utilizes several types of fabrics under two major categories, natural and synthetic. Natural fabrics are those that naturally occur from animals and plants, while synthetic fabrics are man-made and created in a laboratory.

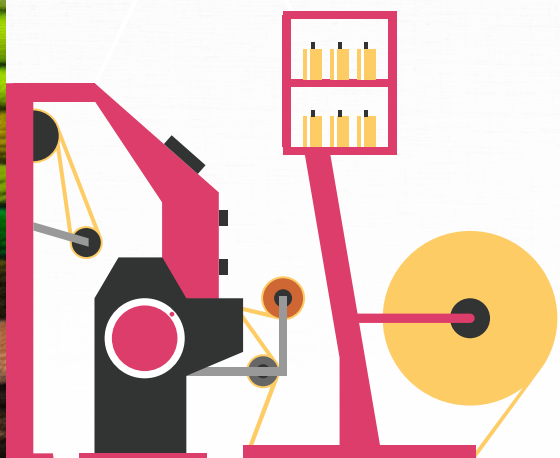
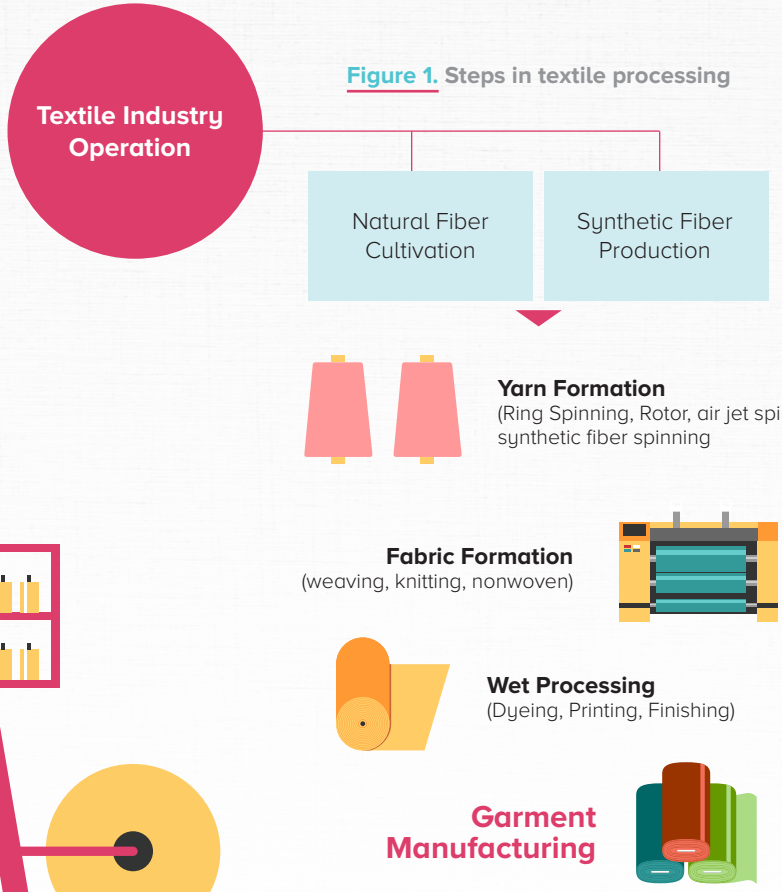


Figure 1. Steps in textile processing



It is a fact that the textile industry has grown multiple times over the last decades to meet the global demand. The global textile market size was projected at USD 1000.3 billion in 2020 and is now expected to grow at a compound annual growth rate (CAGR) of 4.4% from 2021 to 2028.[2] This industry is of a prime significance to emerging economies and developing countries, as these countries are seeing an explosion in the growth of their textile exports.

However, this tremendous growth has also led to a parallel growth in the use of chemical substances such as dyes in the textile sector, which has largely remained unnoticed. Several toxic chemicals used in the textile industry not only lead to environmental, but also health problems. Further, the textile industry has significantly contributed to environmental challenges, in terms of the discharge of large amounts of toxic chemical load.

This results from the high consumption of water and toxic chemicals used in this sector and the associated water pollution, in addition to high energy consumption in production processes and the related air emissions.[3]

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Chemicals in textiles: An Overview

The textile industry has undergone many changes during these years and has developed from the simple bulk items that used to be produced initially, to the diverse products that are nowadays manufactured using advanced products and technologies. These products include smart textiles, all of which involve the use of hazardous chemicals. Many of these chemicals can be found in the finished textile products and a fraction of them also end up in wastewater or water after washing or chemical cleaning of textiles.

The growth of the textile industry leads to an increase in the chemicals used in textile processing, and the market value of it is estimated to be

31.8 bn USD

by the end of 2026.

Chemicals are used in textiles for different purposes and to deliver a certain effect to a product. A range of uses of these chemicals include biocides to stop mould from growing on shoes, dyes to give specific colours to clothes, and water repellents to make outdoor wear more practical. Oils and greases, starch, sulphonated oils, waxes, and some surfactants are also used in textile finishing for stiffening textiles and making them wrinkle-free. Moreover, chemicals are also used to make textiles more resistant to water, stains, wrinkles, bacteria, and mould.[4] However, some of these chemicals can be harmful and are of a very high concern from the point of view of human health and the environment.

The textile industry is the second largest polluter of fresh water worldwide.[5] Up to 3500 chemical substances are used to turn raw materials into textiles. The global textile chemicals market was valued at USD 21.23 Billion in 2020. Approximately 10% of these chemicals are hazardous to human health or the environment. Some of the chemicals may persist in the environment, build up in the body, and affect immune and reproductive systems.

The important chemicals used in different stages of textile manufacturing are highlighted in Table 1.

Table 1 **Potentially toxic chemicals or chemical classes used in different stages of textile and clothing manufacturing and their functions**[6]

Process step	Chemicals or chemical groups used	Function/product specifics
Fibre production	Pesticides, detergents	Remove wool impurities
	Heavy metals	Viscose, Polyester
Knitting	Mineral oils, including polyaromatic hydrocarbons	Lubricating/emulsifying
Washing	Organic solvents, nonylphenols/nonylphenol ethoxylates (NPEOs)	Detergents in washing
Desizeing	Pentachlorophenol	Remove starch sizes
Dyeing or printing	Azo dyes	Used for dyeing
	Heavy metals	Attach dyes to fibre
	Organochlorines (chlorinated solvents, chlorinated benzenes)	Carriers
	Solvents, formaldehydes, NPEOs	Auxiliary substances
Stabilizing	Formaldehyde, triazones, carbamates	Stabilizing of cellulose fibre
Fire-proofing	Heavy metals, halogens, salts, formaldehyde, brominated flame retardants (BFRs), short-chain chlorinated paraffins (SCCPs), and asbestos	
Biocide treatment	Metals, SCCPs, triclosan, organotins	Anti-mould or anti-microbial
Anti-pilling, water proofing	Phthalates, heavy metals, organotins, perfluorinated compounds (including PFOS, PFOA)	Cotton, polyester
Protective printing inks	Phthalates, heavy metals, organotins	Depend on fabric and use
Water, oil, stain, and wrinkle-resistant coatings	Formaldehyde, perfluorinated compounds (including PFOS, PFOA)	
Dry cleaning	Tetrachloroethylene, trichloroethane, chlorofluorocarbons	
Transport and storage	Chlorinated phenols	Added as biocides

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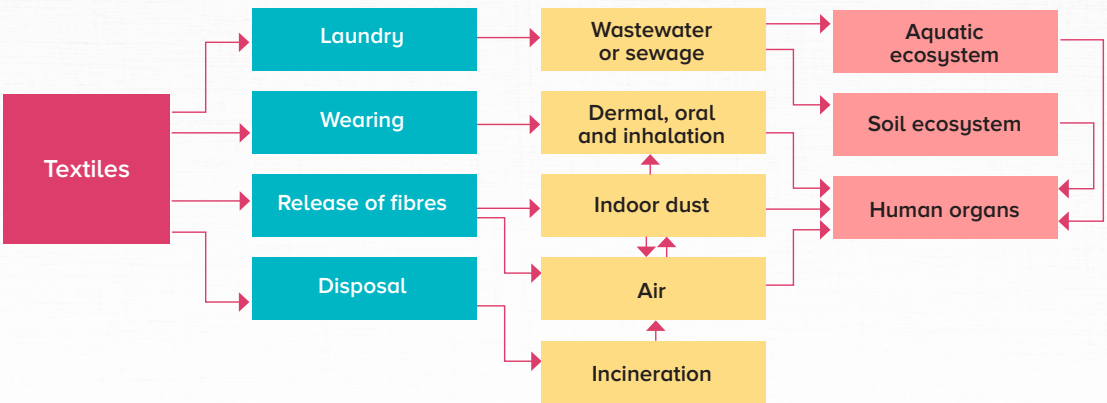
Release of Chemical from Textiles

Chemicals released from the textiles into the environment occur in various forms and are an emerging pollution issue globally. The effluents released from textiles is complex and contain a high concentration of pollutants, such as polycyclic aromatic hydrocarbons, heavy metal ions, surfactants, dyes, solvents, detergents, and recalcitrant compounds. Moreover, several studies indicate the leaching of chemicals from finished products, which is of concern for environmental and human health.

Numerous studies on the presence of chemicals in textile products have been carried out over the years, including those on biocides[7], hexabromocyclododecane flame-retardants[8], per-, and polyfluoroalkyl substances[9,10], formaldehyde[11], nonylphenol ethoxylates[12], azo-dyes, and their reduction products[13], polychlorinated dibenzo-p-dioxins, dibenzofurans, and octachlorodibenzofuran[14], etc.



Nevertheless, when we wear clothes, toxic compounds in the fabric may be leached onto the skin. This leads to dermal absorption and systemic exposure. There are studies that have pointed out the transfer of organic compounds from contaminated textiles to the outermost layers of the skin.[15–17] Although the major exposure to textile chemicals takes place through skin contact, other uptake routes such as the migration of substances into the air, or due to wear, fibers can be released into the air and can enter the human body through inhalation or ingestion.

Chemicals from textiles such as dyes are also released into the environment during washing, and thus contaminating the aquatic water system. The pattern for chemical release from textiles is shown in Fig. 2.

Children are vulnerable to chemicals in textiles

The developing foetus, infants, and children are particularly sensitive to chemicals and their toxic effects, and their impacts can cause life-long health effects. The foetus developing in the womb can be exposed to chemical substances that might be present in the mother's blood, either from daily exposure to chemicals or from chemicals that have been stored in her tissues and released during pregnancy. Infants and children can directly ingest chemicals present in clothing by chewing or sucking them. This particular behaviour of children to nonylphenol ethoxylates in children wear is described and assessed in a study by the Danish Ministry of the Environment.[18] House dust is also an important exposure pathway in young children.[19] Contamination in house dust makes continuous exposure to harmful chemicals possible, via inhalation, ingestion, or direct skin contact.

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Potential Toxics Chemicals used in Textiles

The major chemicals of concern in the textile industry can be mapped into six broader groups.

Amines

Amines are a broad class of nitrogen-containing compounds that can be used as building blocks for dyes, polymers, and surfactants. They are used to perform different functions within the textile supply chain.

Halogenated chemicals

These chemicals contain one or more of the halogen group elements, Fluorine (F), Chlorine (Cl), Bromine (Br), or Iodine (I) covalently bonded to carbon. Some of the major halogenated textile chemicals include perfluorinated surfactants and brominated flame retardants.

Heavy metals

Heavy metals are used in dyes and as catalysts or formulation aids in resins and synthetic fibers. Some functions, such as catalyzing polymerization, can only be accomplished with metals.

Monomers

Monomers are the building blocks of synthetic fibers and resins. They must be reactive to perform their function and are hazardous to human and environmental health before they have been polymerized or cured.

Solvents

Large quantities of solvents and process aids are used to transfer the chemistry onto fabric and/or remove the residuals. Some solvents fulfill specific functions, such as dimethylformamide, used in foaming polyurethane, while others are used for many applications, such as the aromatic solvents used for cleaning or dispersion of dyes. In most cases, multiple solvents can be used for the same function.

A wide range of chemicals are used in the textile industry to serve different purposes; however, nowadays some of the chemicals of concern frequently occur in textile products. These chemicals of concern and their properties, toxicity, use, and regulations are discussed below in detail.

4.1 Per-and polyfluoroalkyl substances (PFAS)

PFAS, which stands for per- and polyfluoroalkyl substances, are a widely used group of thousands of highly persistent man-made chemicals (Fig. 3). PFAS have been manufactured and used in a variety of industries around the globe since 1940s. Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) have been the most extensively produced and studied among these chemicals.[20] Some of the major industry sectors using PFAS include aerospace and defence, automotive, aviation, textiles, leather and apparel, construction and household products, electronics, fire-fighting, food processing, and medical articles.

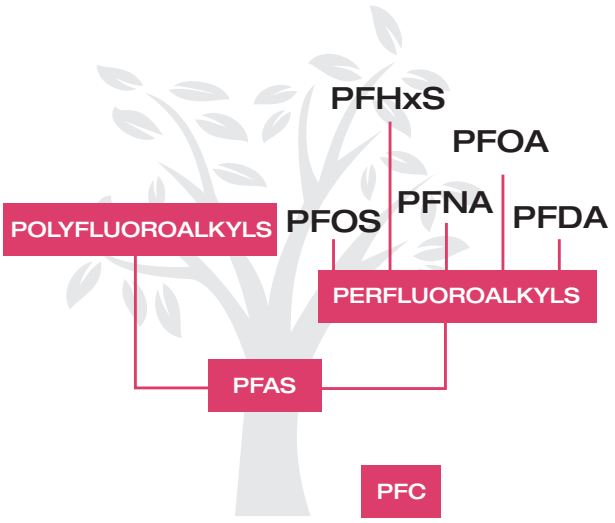


Figure 3. Family Tree of PFAS

There are over 9200 structurally diverse PFAS structures.[21] The carbon-fluorine bond is one of the strongest; therefore, these chemicals do not degrade in the environment and remain in the environment for a longer period. Because of their widespread use and their persistence in the environment, these chemicals are contaminating air, soil, water, plants, wildlife, and even our bodies. Some PFAS can get accumulated in humans and animals with repeated exposure over time.[22] The Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey conducted a study in 2015 and found PFAS in the blood of 97% Americans.[23]

Widespread Occurrence	Exposure from several products	Growing numbers of new forms of chemical	Persistent	Bioaccumulation

Concerns associated PFAS

Uses in textiles

The textile industry has been identified as the largest user of fluorotelomers, a major subgroup of PFAS.

As per the report, **45,000 to 76,000** metric tons of select PFAS are used for textile products in the EU annually. Among these uses, home textiles and consumer apparel are the two dominant categories. However, EU has started restricting the use of PFOA and PFOS in textile use since 2020 and also considering the restriction of other PFAS.

PFAS are widely used in textile products, including fashion apparel, uniforms, sportswear, outdoor gear, footwear, carpets and rugs, bed and bath products, backpacks, swimwear, and upholstery. These chemicals are able to repel oil and dirt. Therefore, they are applied as a thin film on the fabric surface during the finishing stage, usually in combination with other finishing chemicals. **The functions of PFAS in various textile products include water repellence, oil repellence, stain resistance, soil protection, and flame-retardancy**. **In addition, PFAS-based impregnation agents are used in textile products to provide alcohol repellence and a high level of washing and dry-cleaning durability**.

The functions of PFAS in various textile products include **Water Repellence, Oil Repellence, Stain Resistance, Soil Protection, and Flame-Retardancy.**

Release of PFAS from textiles

PFAS can be released at three different phases of the lifecycle of textiles: manufacturing, use, and disposal. The release mechanisms from these stages are summarized below:

Release during Textile Manufacturing:

The manufacturing of some high-performance textiles involves many chemical treatment steps using PFAS. A study by Heydebreck et al. has reported the presence of PFAS in wastewater, air, airborne particles, and settled dust in a textile manufacturing facility. PFAS in textile products can be released into domestic wastewater treatment plants through laundry during washing, while a significant portion of PFAS from manufacturing waste streams are released into industrial wastewater treatment plants.

Release during Textile use:

PFAS-treated clothes undergo a reduction in repelling property over time. PFAS can be released from clothing in several ways such as:

- Evaporation of residual volatile PFAS;
- Wash-out of water-soluble residuals like PFOA;

- Loss of particles and fiber fragments containing these compounds by abrasion or during washing;
- Chemical breakdown of these polymers during laundering

Release during Textile disposal:

Many textile products (e.g., carpet and clothing) are disposed of in landfills at the end of their useful lives. The studies conducted by Lang et al. found about 70 PFAS compounds in the landfill leachate which can contaminate the surrounding ecosystem..[24]

Health effects:

Health effects associated with well-studied PFAS such as PFOA and PFOS include cancer, hormone disruption, liver and kidney damage, reproductive harm, increase in cholesterol levels, and immunological changes.[25] Unborn babies can be exposed to PFAS from their mothers during pregnancy. Newborns can also be exposed to PFAS through breast milk. Exposure to PFAS may lead to low infant birth weights and hinder their development. PFAS can affect the survival, growth, development, and reproduction of aquatic and terrestrial animals. Some studies suggest that PFAS can affect the immune system in children and induce hyperactivity.

Regulations in phasing out PFAS

After the toxic impacts of PFAS surfaced, the regulatory landscape for PFAS started changing rapidly. At the global scale, action has been taken under the Stockholm Convention (SC) to limit the production and use of PFOS and related compounds. It started by listing these compounds in Annex B of SC in 2009 and subsequently strengthened in 2019 with the addition of PFOAs in Annexure A of the Stockholm Convention[26]. In addition, PFHxS and its related compounds are now proposed for listing under the Convention.[27]

In line with the SC, the EU has restricted PFOA and PFOS. Several other PFAS are on the EU Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) list of Substances of Very High Concern (SVHC).[28] PFOA and PFOS are also priority hazardous substances under the EU Water Framework Directive.[29] Denmark, Germany, the Netherlands, Sweden, and Norway have announced to formally propose to the European Chemicals Agency (ECHA) that the entire class of these chemicals be restricted under REACH, covering all uses.[30,31]

More than 1300 PFAS compounds and chemicals have been identified in the Toxic Substances Control Act (TSCA) US EPA Inventory as of April 2021. The US EPA recently issued a “significant new use rule”, requiring companies to notify the Agency at least 90 days before engaging in any new use of certain long-chain PFAS.[32] This rule particularly affects imports, and it applies to consumer products that may have PFAS on them as surface coatings, such as apparel, carpets, and furniture.

Some states in the US have implemented various approaches for restricting the use of PFAS as a class. For example, Maryland has banned PFAS in furniture, mattress foam, and children products in 2020, and Minnesota prohibited the use of some PFAS in certain types of furniture and children products in 2019.[33] Further, the California Department of Toxic Substances Control (DTSC) adopted a new “Priority Product” directive under the state’s Safer Consumer Products Program. Based on this directive, the businesses that manufacture, import, distribute, sell, or assemble carpets and rugs containing PFAS that are sold in

China adopted a few voluntary initiatives that limit PFAS chemicals in textile products, such as the **"Technical Requirement for Environmental Labeling Products: Textile Products."**

California will have to provide DTSC notice and will need to evaluate alternatives to using PFAS.[34]

China adopted a few voluntary initiatives that limit PFAS chemicals in textile products[35], such as the "Technical Requirement for Environmental Labeling Products: Textile Products." This voluntary initiative aimed at environmental labeling was implemented in 2017 and only covers two individual PFAS substances: PFOA and PFOS. Recently, China published a voluntary standard "Guidelines for the Use and Control of Key Chemical Substances in Consumer Products" which covers more long-chain PFAS chemicals and also applies to a wider range of products.[36]

Currently, India does not have a regulatory mechanism or framework for the use of PFAS. India has supported the inclusion of PFOAs but has not supported the inclusion of PFOS in the SC. India has also rejected the inclusion of PFOS and any other PFAS chemicals on its global restriction list. However, as a first step towards developing a framework for regulating and governing PFAS, the Bureau of Indian Standards (BIS) announced in 2020, that it would adopt the PFOS and PFOA International Standards Organization (ISO) benchmarks in water as Indian Standards.

Five non-fluorinated products, which are available in the market as alternatives to PFAS are:[37]

- Paraffin repellents
- Stearic acid-melamine repellents
- Silicone repellents
- Dendrimer based repellents
- Nano-material based repellents

4.2 Nonylphenol Ethoxylates (NPEOs)

Alkylphenol ethoxylates (APEOs) are very widely used as detergents, emulsifiers, wetting and dispersing agents, antistatic agents, demulsifiers, and solubilisers in domestic, agricultural, and industrial products. The most widely used APEO is nonylphenol ethoxylate (NPEO), which accounts for 80 to 85% of all APEOs produced followed by octylphenol and dodecylphenol ethoxylates (OPEO and DPEO).

NPEOs are a group of chemicals used as surfactants, emulsifiers, dispersants, and wetting agents in a variety of applications, including the manufacture of textiles. When released, either directly into surface

waters or via wastewater treatment facilities, NPEOs can break down to form nonylphenols (NP), a closely-related group of persistent, bioaccumulative, and toxic chemicals.

Uses in textiles

NPEOs with 7 to 15 ethoxylate units are mainly used in the manufacture of textiles. However, short-chained NPEOs with 4 to 6 ethoxylate units and long-chained NPEOs with more than 30 ethoxylate units are also used in the production of textiles.[38]

NPEOs have been used in textile processing for the following purposes:

- Auxiliary agents for cleaning and rinsing of textiles, especially wool and to some extent cotton, from which fat and other impurities must be removed for better dyeing
- Dyeing cotton, acrylic, and polyester
- Auxiliary agents in bleaching because they increase the ability of the bleaching agent to penetrate the textile
- Wetting agents for textiles
- Emulsifiers for oils for textile fibers

Thus, NPEOs are used in several process steps, including washing, dyeing, and bleaching processes. In a 2012 Greenpeace study[39] carried out in 27 countries including India, **NPEOs** were most commonly identified in 89 of the 141 high street fashion textile products, up to 45000 ppm. Three out of nine clothes purchased from India also had **NPEOs**. In the subsequent Greenpeace study conducted in 2013,[40] **NPEOs** were detected in 50 textile products.

Release of NPEOs from textiles

Recent investigations in textile manufacturing hubs such as Thailand, China, Mexico, and Indonesia have shown that NP/NPEOs are among the most commonly detected toxic chemicals in the effluents from wastewater treatment plants (WWTPs).[41] This implies the releases of NP/NPEOs to the environment from manufacturing facilities. In addition, NPEO residues

NPEOs degrade to NP within hours or days and NP is a major health and environmental concern. Concerns about NP include:

- Very high persistence, bioaccumulation, toxicity potential
- Very high acute (short-term) aquatic toxicity, high chronic (long-term) aquatic toxicity
- Moderate concern for developmental, reproductive, endocrine and other health effects
- Very high skin/eye irritation

within textile products are readily released when the items are washed as part of their normal use. The release of NPEOs from the washing of clothes and other fabric products contributes NP to surface waters, predominantly via urban wastewater and sewage treatment plants.[12]

Health effects

As endocrine-disrupting chemicals (EDCs), NPEOs mimic estrogens, thus affecting the hormonal system and lead to potential reproductive problems. The NP can have adverse effects on reproductive, immune, and central nervous systems. They have been detected in fish, rats, birds, and humans with possible abnormalities in embryos and offspring.[42] NPEOs can also interfere with the critical steps involved in the development of the brain. Some of the impacts of NP on the aquatic environment include feminization of aquatic organisms, decrease in male fertility, and lower survival rate of juveniles. Recent studies have associated exposure to NP with breast cancer in women[43] and prostate cancer in men.[44] One of the most common effects of NP on plants is general growth inhibition, characterized by reduced biomass and length and reduction in germinative capacity.

Global Regulations on NPEOs

NP and NPEO are covered under REACH Regulation[45], limiting the use of these substances, including in textile products. According to this regulation, washable textile articles shall not be placed on the market after February 2021, if, the NPEO concentrations are equal to or greater than 0.01% by weight of that textile article, or of each part of the textile article.[46]

NP is on the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) list of dangerous substances[47] and on the Water Framework Directive list of priority hazardous substances.[48]

In 2018, US EPA added NPEOs to the list of toxic chemicals, subject to reporting under section 313 of the Emergency Planning and Community Right-to-Know Act (EPCRA), and section 6607 of the Pollution Prevention Act (PPA).[49] California Department of Toxic Substances Control (DTSC) issued a public notice in 2018 proposing to list NPEOs in laundry detergent as a priority product under safer consumer products regulations.[50]

In 2016, South Korea restricted the import, sale, storage, transport, or use of NP and NPEOs under the Korean Act on the Registration and Evaluation of Chemicals (K-REACH). The regulation requires that the quantity of the compound shall not exceed 0.1% for any products or components within.[51]

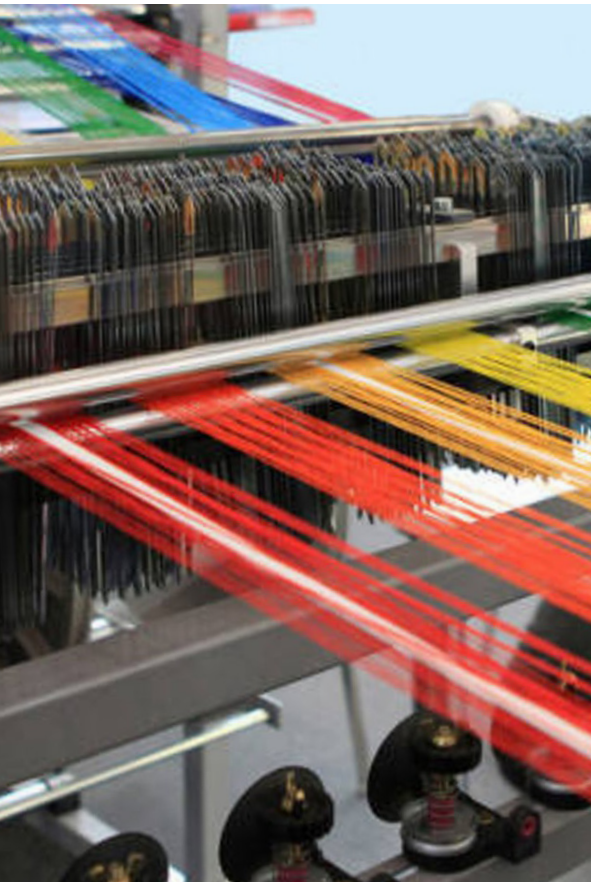
In 2009, India has prohibited the use of NP in cosmetic products[52], but there is no regulation on its use in surfactants or other consumer products including textiles. These chemicals are also not on the list of hazardous substances monitored by Ministry of Environment, Forest and Climate Change. There are no specific standards for NP or NPEOs in water and wastewater, only the standards for phenolic compounds are listed in the standards for drinking water.

Alternatives to NPEOs

To date, alcohol ethoxylates are the most commonly used products to replace NPEOs. Another alternative to APEOs is the use of sulfur-based anionic emulsifiers and dispersants such as alkyl or aryl ethoxy sulfates, sulfonates, and alkyl sulfates.[53]

4.3 Decabromodiphenyl Ether (decaBDE)

Polybrominated Diphenyl Ethers (PBDEs) are brominated hydrocarbons in which 2–10 bromine atoms are attached to the molecular structure. PBDEs exist as mixtures of distinct chemicals called congeners with unique molecular structures. There are three types of commercial PBDE mixtures, including pentabromodiphenyl ether (pentaBDE), octabromodiphenyl ether (octaBDE), and decabromodiphenyl ether (decaBDE). decaBDE is the most widely used PBDE globally that is added to plastics, textiles, and other materials to retard combustibility. It has been listed in Annex A of the SC. decaBDE degradation may also lead to the formation of lesser-brominated PBDEs and other toxic metabolic products in organisms.



Uses in textiles

decaBDE is used for the treatment of certain textile fabrics (those associated with transportation, public spaces, high-risk occupancy areas, military, etc.) to achieve high fire resistance.[54] decaBDE is commonly used in upholstery, window blinds, carpet backings, curtains, and mattresses in homes, hospitals, and other buildings. The most popular fabrics treated with decaBDE are blends of polyester, acrylic, and viscose fibers. decaBDE is also likely to be used in foam for furniture and cushions.[55]

Health effects

The impact of decaBDE on the environment and human health are well studied. decaBDE bioaccumulates in several species of fish, birds, and mammals and has the potential to interfere with the food chain. Further, decaBDE is transported through the blood, cord blood, and placenta; therefore, foetuses can be affected. Exposure to decaBDE during critical child development period can have serious impacts on their growth, causing severe lifelong consequences on their physical and mental health. Negative effects of decaBDE have been

observed on the liver, thyroid, reproductive system, and neurological development.[56] decaBDE is found to be toxic to aquatic invertebrates, fish, and terrestrial invertebrates. There is also some evidence that decaBDE could potentially cause cancer.[57]

Global regulations on decaBDE

decaBDE is listed under Annex- A of the SC on POPs with specific exemptions for the production and use of commercial decaBDE, such as for use in textile products that require anti-flammable characteristics, excluding clothing and toys, critical spare parts for the automotive and aerospace sector, polystyrene and polyurethane foam for housing insulation, etc.

In the US, the states of Maine, Washington, Vermont, and Oregon had restricted the use of decaBDE in certain products, but still many major uses of the substance were allowed.[58] However, in June 2021, the US EPA has come up with a rule that prohibits all manufacture (including import), processing, and distribution in commerce of decaBDE, or decaBDE-containing products or articles, with some exclusions.[59] For example, decaBDE is prohibited in any manufacture, processing, and distribution for use in curtains in the hospitality industry, and the curtains to which decaBDE has been added.

In 2017, the EU published Regulation (EU) 2017/227 under REACH to prohibit and/or restrict decaBDE as a substance, constituent of substances, in mixtures and articles effective from March 2019.[60] decaBDE has also been on the Candidate List of SVHC for authorization since December 2012.[61] In Norway, decaBDE is banned since 2008, including in textiles.[62]

Recently, in October 2021, China has released a draft plan for new chemical pollutants management, which includes banning the production, processing, use, import, and export of decaBDE, SCCPs, and other compounds in phases by the end of 2025.[63] Japan's Ministry of Economy, Trade, and Industry (Meti) has added decaBDE and SCCPs to the list of Class -I specified chemical substances under the Act on the Evaluation of Chemical Substances and Regulation of Their Manufacture, etc. The manufacture and import of such substances are banned and their use restricted.[64]

Currently, India does not have any specific policy for decaBDE. But according to E-Waste (Management) Rules, 2016, new electrical and electronic equipment and their components or consumables or parts should not contain polybrominated diphenyl ethers beyond a maximum concentration value of 0.1% by weight in homogeneous materials following some of the provisions of EU's RoHS Regulations.

decaBDE alternatives use in textile

European Commission and US EPA identified various alternative flame retardants for textile fabrics and analysed their hazard profiles such as, magnesium hydroxide, tris(1,3-dichloro2-propyl) phosphate (TDCPP), aluminium trihydroxide, ethylene bis(tetrabromophthalimide) (EBTBP), 2,2'-oxybis[5,5-dimethyl-1,3,2- dioxaphosphorinane] 2,2'-disulphide, red phosphorus, ethane-1,2- bis(pentabromophenyl) and 1,3,5-triazine2,4,6-triamine (melamine). However, the best alternative shortlisted by EU risk assessment process (ethane-1,2- bis(pentabromophenyl), is also a potential threat for the environment due to its persistency.

4.4 Organotin Compounds

Organotin Compounds (OTCs) (Stannanes) are substances composed of tin (a metal) directly bound to different organic groups.[65] OTCs are among the most widely used organometallic compounds (compounds containing organic groups bounded to metal) for agricultural, industrial, and biomedicinal applications. OTCs vary in their chemical and biological properties; however, most commercial organotins have very low water solubility.[66] Some organotins may persist in the environment and can be toxic to aquatic life above certain exposure levels. Above certain concentrations, some organotins may also act as immunotoxins.[67] They are widely used as polyvinyl chloride (PVC) stabilizers, biocides, or antifouling paints. Therefore, they are omnipresent in the environment. Examples of OTCs are:

- Tributyltin (TBT) Compounds
- Trimethyltin (TMT) Compounds
- Triphenyltin (TPhT) Compounds
- Tetrabutyltin (TeBT) Compounds
- Tricyclohexyltin (TCyHT) Compounds
- Trioctyltin (TOT) Compounds
- Tripropyltin (TPT) Compounds
- Dibutyltin (DBT) Compounds
- Dioctyltin (DOT) Compounds
- Dimethyltin (DMT) Compounds
- Monobutyltin (MBT) Compounds
- Monoctyltin (MOT) Compounds

Uses in textiles

Most OTCs are used in textiles for three major applications as given below:

- **PVC heat stabilizers**

  Mono- and di-organotins (e.g.,DMT, DBT, and DOT compounds) are extensively used as heat stabilizers for processing PVC. The main purpose of these stabilizers is to reduce polymer degradation during high-temperature processing.

- **Catalysts**

  The most common application of OTCs (e.g., DBT) is to speed up chemical reactions, especially polymerization of polyurethane, polyester, and silicones. DBT has been used a catalyst in the curing of urethane coatings and polyurethane foam production. It is also used for esterification and transesterification reactions, such as in the production of polyesters.

- **Biocides**

  OTCs are used as active ingredients in anti-fouling agents, fungicides, insecticides, and bactericides e.g., TBT is sometimes applied to socks, shoes, and sportswear for its anti-microbial function to prevent unpleasant odors caused by sweat. Organotin compounds were detected in sections of printed fabric from 3 articles (of 21 tested), and in materials from 3 footwear articles (of five tested) in the 2013 Greenpeace study.[40]

ISO 22744-1:2020 specifies a test method for the qualification and quantification of organotin compounds in textiles and textile products.[68]

Health effects

The use of OTCs in consumer products has been found to pose a risk to human health and is classified as a "**hazard to human health**". The toxicity of OTCs depends on which organic functional groups are bonded to tin. In mammals, including humans, OTCs can have negative impacts on the heart, nervous system, immune system, reproductive system, endocrine system, etc.[69] TBT and triphenyltin have been shown to contribute to obesity. Triphenyltin is an immunodepressant[70]; while TBT also negatively affects the male reproductive system.[71] Organotins are very toxic to marine and freshwater organisms even at very low concentrations.[72]

Global regulations on OTCs

EU has officially banned specific OTCs in consumer products. For textile materials, the notable restricted substances under REACH regulation include OTCs. According to this regulation, the usage of compounds such as TBT and TPT compounds, DBT compounds, and DOT compounds in consumer products or part of a consumer product shall not be greater than 0.1% by weight of tin.[73]

The American Apparel & Footwear Association (AAFA) has included OTCs in its Restricted Substances List (RSL). This list restricts or bans certain compounds in finished home textile, apparel, and footwear products around the world.[74] TBT and TeBT are included under Prohibition of Certain Substances Regulation, 2012 of the Canadian Environmental Protection Act, 1999.[75]

Following the footsteps of the EU and USA, many Asian countries have either drafted or established their own consumer safety regulation for textiles and clothing. Organotins are restricted by Japan, South Korea, and Taiwan. For example, the safety requirement of TBT in coated or printed textiles for children (36 months to 13 years of age) in Korea is 0.1 mg/kg.

Indian Standards for Organic Textiles (ISOT) developed under the National Programme for Organic Production (NPOP) has included OTCs in the prohibited substances during textile processing.[76]

Alternatives to Organotin Compounds[77]

- Calcium-zinc stabilizers may be used in the form of metal carboxylates
- Organic-based stabilizers are calcium-zinc stabilizers with zinc replaced by organic costabilizers. Calcium-organic is mentioned by the European Commission as a "key alternative" to organotin stabilizers, too
- Bismuth, titanate, titanium, and zirconium catalysts can be used for polyurethane (PU) production
- Titanate catalysts can be used for polyester production

4.5 Phthalates

Phthalates are a group of chemical compounds used in the production of plastics such as PVC, to make them softer and more flexible. They are often called plasticizers and are categorized as “high” or “low,” depending on their molecular weight. First introduced in the 1920s, phthalates are used in a wide variety of products such as building materials, personal-care products, medical devices, pharmaceuticals, food products, and textiles. In short, they are contained in several everyday-plastic products.

Use in textiles

Phthalates have multiple uses in textiles and some of the major applications include screen printing and coating of fabrics. PVC first needs to be softened and plasticizers such as phthalates are used for the same. One commonly used plasticizer, being used in large quantities in the print is phthalates, often around 30–60% of the total composition. As phthalates are not chemically bound to the PVC and can leach out, users are likely to be exposed to and ingest the phthalates from the textiles, for example, through fiber dust. The presence of phthalates in textiles has been reiterated in various studies. **Phthalates** were found in high street fashion textile products, which featured medium or large plastisol printed areas in the study conducted by Greenpeace.[39] Similarly, in another Greenpeace study, **phthalates** were detected in concentrations above 3 mg/kg in sections of printed fabric from 33 of the 35 textile articles tested globally.[40]

Health Effects

Many phthalates are hormone-disrupting chemicals that interfere with the male sex hormone, (testosterone) production. Interference with testosterone activity, especially in early life, can have irreversible effects on male reproduction. One study found that there is a direct relationship between exposure of the mother to phthalates during pregnancy and changes in the ways the genitals of a baby boy develop.[78]

Phthalate exposures in humans have been linked to changes in sex hormone levels, altered development of genitals, and low sperm count and quality. They can lead to obesity, reduced female fertility, preterm birth, and low birthweight, worsening allergic and asthma symptoms, and altered toddler behavior.[79]

Global Regulations on Phthalates in Textiles

(Entry 72 of Annex XVII of the European REACH Regulation) As of 1 November 2020, bis(2-methoxyethyl) phthalate, diisopentylphthalate, di-n-pentyl phthalate, di-n-hexyl phthalate, and 1,2-benzenedicarboxylic acid; C7-rich di-C6-8-branched alkylesters, are restricted in textiles, clothing, related accessories, and footwear at concentrations higher than 1000 mg/kg (individually or in combination with other phthalates listed in Annex XVII of REACH).[80]

The **International Organization for Standardization** (ISO) has published a global standard on **phthalates in textiles**. Standard **EN ISO 14389:2014** covers the determination of ten phthalates in coated or printed textiles by using ultrasonic extraction with tetrahydrofuran.

In 2020, the South Korean Ministry of Trade, Industry, and Energy (MOTIE) has strengthened its common safety standards, wherein companies must ensure that the total content of phthalates in children's products does not exceed 0.1%.[81]

Alternative plasticizers

Examples of alternate plasticizers are acetyl tributyl citrate, di-isononylcyclohexane-1, 2-dicarboxylate, epoxidized soyabean oil, alkylsulphonic phenyl ester, tri-2-ethylhexyl trimellitate, acetylated monoglycerides of fully hydrogenated castor oil, etc. However, most of these alternative plasticizers are not well studied concerning their potential effects on human health and the environment.

4.6 Bisphenol A (BPA)

Bisphenol A (BPA) is found in polycarbonate plastics and epoxy resins. Polycarbonate plastics are often used in containers that store food and beverages, such as water bottles. Epoxy resins are used to coat the inside of metal products, such as food cans, bottle tops, and water supply lines. BPA is also commonly used in clothes and involved in the manufacturing of many synthetic fibres, such as polyester, nylon, and spandex.

Use in textiles

BPA-based antioxidants are used as additives in textiles is to prevent or delay the oxidation and degradation reactions in the extrusion and spinning processes involved in the production of synthetic fibres and yarns. In addition to antioxidants, BPA is used in the production of flame retardants, and as an intermediate in the manufacture of polymers, fungicides, and dyes.[82]

Health effects

BPA is classified as toxic to reproduction (category 1B) and skin sensitizer (category 1) under EU regulations. It also exhibits endocrine-disrupting activity, adversely affecting the female reproductive system and mammary glands. Recently, BPA has also been suspected to impair the development of the immune system, due to its resemblance to estrogen hormone.[83]

Regulations on BPA

Canada became the first country in 2010 to declare BPA a toxic substance. There is no direct restriction on the use of BPA in textiles in most countries. BPA is included in the SVHC Candidate List under REACH regulation.[83] Moreover, textile products being granted the EU Ecolabel are prohibited to contain excessive BPA.[84] The OEKO-TEX® Association (International Association for Research and Testing in the Field of Textile and Leather Ecology) have limited BPA for certain product classes.[85]

Alternatives to BPA

Many bisphenol analogues such as BPF (4,4′-methylenediphenol), BPS (bis(4-hydroxyphenyl)sulfone), and BPAF (2,2-bis(4-hydroxyphenyl)hexafluoropropane) have been produced to replace BPA in various applications. However, they are neither considered safer than BPA nor synthesized from renewable sources. Several chemicals have thus been proposed as substitutes for BPA, some even obtained from plant biomass derivatives, e.g., isohexides, furanic diols, etc.

Short Chain Chlorinated Paraffins (SCCPs) are a mixture of chlorinated hydrocarbons with a chain length of **10 to 13 carbon atoms, and chlorine content of**

40 to 70%

4.7 Short Chain Chlorinated Paraffins (SCCPs)

Short Chain Chlorinated Paraffins (SCCPs) are a mixture of chlorinated hydrocarbons with a chain length of 10 to 13 carbon atoms, and chlorine content of 40 to 70%. SCCPs are persistent and not easily degraded by natural mechanisms. They are persistent, bioaccumulative, environmentally mobile, biotoxic, and endocrine disruptive. SCCPs constitute an emerging group of POPs, which are classified as endocrine disruptors and possible carcinogens to humans (group 2B).[86]

Use in textiles

SCCPs may be used as flame retardants or plasticizers in plastics, rubbers, inks, paints, adhesives, and surface coatings within the textile, apparel, and footwear industries. They also may be used as fatting and softening agents in the leather industry and as impregnation agents in the textile industry.[87]

Environment and Health Effects

SCCPs are classified as dangerous to the environment due to their high toxicity to aquatic organisms even at low concentrations, leading to long-term adverse effects. Excessive exposure to SCCPs may affect the kidney, liver, and thyroid and may cause cancer.

In a commercial Safety Data Sheet (SDS), it is mentioned that SCCPs are suspected of causing cancer and are very toxic to aquatic life with long-lasting effects.

Global Regulations

SCCPs were added to the SC (Annex A) in 2017 with specific exemptions such as secondary plasticizers in flexible polyvinyl chloride, except in toys and children products, use in the leather industry, etc. In the EU, SCCPs are currently restricted under the POPs Regulation. EU has established a regulatory limit of 1500 mg/kg for SCCPs in consumer products and 1% in other CP formulations.[26] SCCPs are also included in the EU list of SVHC of REACH. They are listed in the Canadian Environmental Protection Act (CEPA) as priority substances and by U.S. EPA as extremely hazardous substances. SCCPs are also prohibited under GOTS.[84]

Currently, there is no regulation and legislation for SCCPs in India to control their uses and distribution in the market.

Alternatives to SCCPs

Higher carbon-containing chlorinated paraffins may be used as alternatives to SCCPs e.g., medium-chained chlorinated paraffins (MCCPs), where carbon chain length is C14–17, and long-chained chlorinated paraffins (LCCPs), where carbon chain length is C18 or above. However, the toxicity of these chlorinated paraffins is yet to be investigated.[88] Some of the other compounds identified as possible replacements to SCCPs used in textiles are as follows:[87]

- Acrylic polymers
- Aluminum trihydroxide, used in conjunction with antimony trioxide (ATH)
- Antimony trioxide (or Antimony oxide)
- Bis (tribromophenoxy) ethane

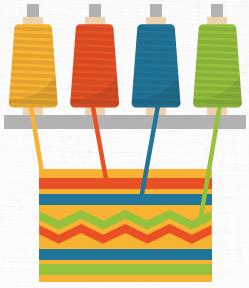
“

The global demand and the export market have led to cutthroat competition among all the manufacturing nations. Therefore, the developing nations, mostly from Asia, such as China, India, Bangladesh, Indonesia, and Vietnam have faced the brunt of the environmental impacts of the textile industry.

05

Textile Pollution and Hotspots

As fashion becomes increasingly globalised, garment and footwear production shifted to most developing countries, thanks to lower manufacturing costs. The global demand and the export market have led to cutthroat competition among all the manufacturing nations. Therefore, the developing nations, mostly from Asia, such as China, India, Bangladesh, Indonesia, and Vietnam have faced the brunt of the environmental impacts of the textile industry. Let us have a look at a few case studies of chemical pollution caused due to textile units in different textile-producing nations.



In China, more than

80%

of all textile factories are located in coastal regions.

In **China**, more than 80% of all textile factories are located in coastal regions. **Antimony, iron, chromium, cadmium, copper, lead, and manganese** have been widely detected in textile and dyeing effluents in **Jiangsu and Zhejiang Provinces**.[89] In a Greenpeace study,[90] the chemicals detected in wastewater discharged to **Yangtze River Delta from Youngor Textile Complex** included **nonylphenol, persistent and toxic perfluorinated compounds, including perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), and other perfluorinated carboxylic acids, amine compounds, tributyl phosphate, chlorinated solvents**, etc. The chemicals detected in wastewater discharged to **Pearl River Delta from Well Dyeing** included **nonylphenol and octylphenol, trialkyl phosphates, dichloroaniline** dye, etc.

China was the largest consumer of textile chemicals, accounting for close to 50% of global value in 2018. China has become the largest market for textile chemicals, based on the ever-increasing apparel and textile production, and the huge production of synthetic fibers and cotton. North America is the second-largest market for textile chemicals because of the higher

value of chemicals consumed in the United States as finishing agents and as binders and coatings in the nonwoven and carpet industries. **China, India, and the United States were the largest consumers of chemicals on a volume basis in 2018.**[91]

Bangladesh is the world's second second-biggest garment manufacturing hub after China, and the industry contributes to 82% of the country's export revenue.[92] The effluents containing heavy metals such as **vanadium, molybdenum, zinc, nickel, mercury, lead, copper, chromium, cadmium, and arsenic** are released in the vicinity of textile industries in the capital city of **Dhaka**. Moreover, this polluted river water is being used for irrigation. The vegetable and fruit samples analysed from nearby the textile industrial areas showed the presence of textile dyes, which can affect the health of the people through the food chain. Other places where metal pollution has been observed in Bangladesh due to the direct discharge of effluents from tanneries and textiles are Chittagong and Khulna.

The Citarum River in Indonesia, with more than 200 textile factories along its bank that discharge their waste water into the river, has been ranked among the most polluted rivers in the world. It is contaminated with chromium, copper, arsenic, lead, and cobalt, because of the effluent discharge from textile industries.[93] Locals even say that the textile dyes are changing the color of the river every day.

Textile Pollution hotspots in India

The textile industry occupies an exclusive place in India and is one of the first industries to come into existence in the country. The industry accounts for 14% of the total industrial manufacturing output. There are over 7000 large-scale textile industries in India, concentrated primarily in Gujarat, Maharashtra, Rajasthan, and Tamil Nadu.

The **Noyyal River** in Tamil Nadu and the **Bandi River** in the Pali district of Rajasthan continue to face devastating consequences because of irresponsible dumping of dyes and chemicals used during textile production.[90] Tirupur's dyeing and bleaching units that add colour to the clothes have turned the once-beautiful **Noyyal River** into a toxic sewer and destroyed vast areas of agricultural land. Studies have shown dangerous levels of **chlorides** and **sulphides** in the **Noyyal River.**

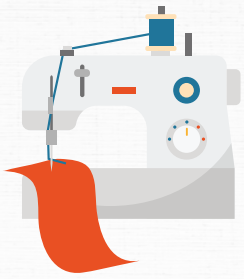
Traces of **phenolic compounds** have been observed in the **Bandi River.** In Haridwar (situated near the Bandi River), groundwater in areas near textile industries showed unsafe levels of **lead, cadmium, chromium, and iron**.

The textile industry in Surat is one of the oldest and most widespread industries. A major part of the city's population is associated with the textile industry. However, the **Tapi River** in Surat was found to be polluted with heavy metals such as cadmium, chromium (hexavalent), lead, and cobalt due to the textile industry's discharge into the river. A 2019 study by Toxics Link also indicated high levels of **nonylphenols** in **Bandi River, Rajasthan, and Tapti River in Surat, Gujarat**.[94]

06

Phase out of Chemicals from Textiles: A Global Call

The chemicals in textiles have emerged as a global environmental problem and therefore, multilateral agencies and countries are taking adequate measures to prevent and minimize the impact of the chemicals used in the textile industry on environment and human health.



As of 2018

80 Companies

including Adidas, H & M, and Mango have worked to reduce the volume of chemicals used in their production processes.

In 2011, Greenpeace launched its 'Detox My Fashion' campaign to call for 80 leading fashion brands and suppliers to reduce their toxic impact on the environment. As of 2018, 80 companies including Adidas, H & M, and Mango have worked to reduce the volume of chemicals used in their production processes. In a follow-up report published in 2018, Greenpeace recognized that 72% of these 'Detox' committed brands have worked towards disclosing their supplier's lists.

There are regulations in place to restrict the use of toxic chemicals in production process as well as on the products, which have an indirect bearing on textiles as well. These regulations are;

Toxic Substances Control Act (TSCA)

Toxic Substances Control Act (TSCA) regulation in the US regulates both, the introduction of new chemicals and the use of existing chemicals. TSCA was introduced in 2016 and was amended by the Frank R. Lautenberg Chemical Safety for the 21st Century Act.

REACH (Registration, Evaluation, Authorisation, and Restriction of Chemicals)

REACH (*Registration, Evaluation, Authorisation, and Restriction of Chemicals*) was founded in 2006 and is an EU regulation devised to regulate the effects of chemical substances on the society and environment. The REACH regulation came into force on 1 Jun 2007, establishing a uniform system for the control of chemicals manufactured or imported to the EU.

MEP Order 7 (also known as China REACH)

This regulation is similar to the EU REACH regulation. Chemical manufacturers and importers are required to submit notifications and obtain approvals before producing or importing chemicals. Several textile chemicals such as PFAS and NPs have been added to the list of severely restricted toxic substances under the Chinese REACH.

The Manufactures Restricted Substance List (MRSL)

The Zero Discharge of Hazardous Chemicals (ZDHC) group consisting of ZDHC member brands and chemical companies developed and published The Manufactures Restricted Substance List (MRSL). The first MRSL was published in 2014. It includes chemical substances banned from intentional use in facilities processing textile materials, leather, rubber, foam, adhesives, and trim parts in textiles, apparel, and footwear. MRSL is important because it not just restricts substances in finished goods but throughout the supply chain.

SAICM (Strategic Approach to International Chemicals Management)

To address the concern of use of hazardous chemicals within the textile and other industries, the **Strategic Approach to International Chemicals Management** (SAICM) was formed in 2006 during the World Summit on Sustainable Development.[95] SAICM is a global, voluntary initiative to support nations with sustainable management of chemicals. The textiles sector is currently considered in the SAICM context through what is known as 'Chemicals in Products Programme'. In addition, within the textile industry, many private standards, certification systems, and labels (SCLs) have emerged for production and product-related chemical management.

07

Chemical in Textiles and Sustainable development goals

The textile industry is one of the most valued industries globally and has hugely contributed to the global economic growth. However, the environmental impact of the textile sector is a growing challenge. The challenges that lie within the textile industry are the type of chemicals being used at the upstream level and the waste being released from these industries at the downstream level. Therefore, it is essential that the textile industry should work towards the promotion of sustainable production processes, as well as adoption of environmentally-sound management systems at the downstream level, which will act as catalysts towards the achievement of the sustainable development goals (SDGs).

Let us take a look at a few of the SDGs which the textile industries need to adopt and act upon to achieve the desired targets;

SDG 5:
Achieve gender equality and empower women and girls

Being mostly a female-dominated industry, the hazardous chemicals used in the textile industry are likely to largely affect women. Therefore, promoting SDG5 is a priority for this sector.

SDG 6:
Ensure availability and sustainable management of water and sanitation for all

The textile industry is extremely water-intensive and generates a huge amount of effluent. Therefore, steps should be taken within the textile value chain to reduce water use, reuse water, and replenish of the resources.

SDG 7:
Ensure access to affordable, reliable, sustainable, and modern energy for all

The textile sector has long identified the call for clean energy solutions and has supported clean energy strategies within its value chains.

SDG 9:
Build a resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation

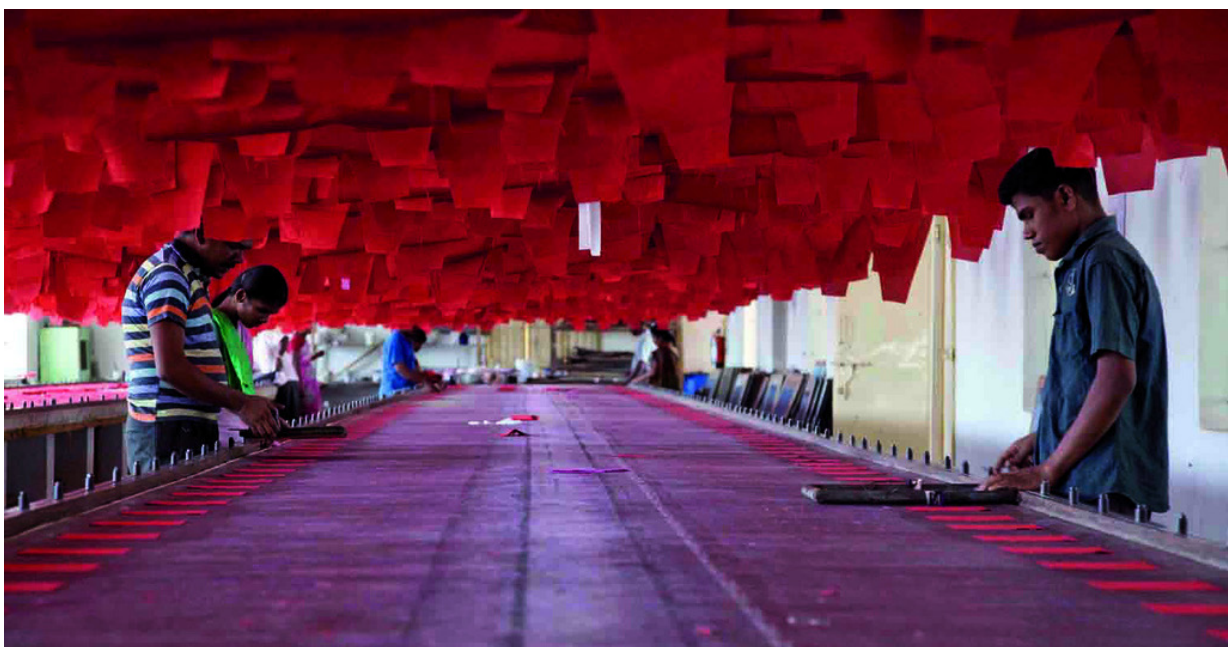
Adopting innovation by upgrading infrastructure and exploring distinct business models with cleaner, sustainable, and environmentally sound technologies is necessary for increased resource-use efficiency.

SDG 10:
Reduced inequality within and among countries

The textile industry can better promote this goal by implementing strategies and methods which assure that human rights are guarded, fair wages are given, unfair habits are eliminated and sustainable and environmental-friendly technologies are adopted.

SDG 12:
Responsible consumption and production – ensure sustainable consumption and production patterns

The textile industry should achieve the environmentally sound management of chemicals to significantly minimize their adverse impacts on human health and the environment.



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Annexure I: Chemicals of concern detected in textile products in different studies

Study	Country	Findings
Greenpeace 2012[12]	18 countries – including 10 within the EU and representing 13 different countries of manufacture	- 52 of the 78 articles showed the presence of Nonylphenol ethoxylates (NPEOs) at concentrations above 1 mg/kg - NPEO levels in plain fabric samples ranged from >1 to 1100 mg/kg - NPEO levels in samples bearing a plastisol print ranged from 5 to 27000 mg/kg
Greenpeace 2013[96]	25 countries/ regions around the world, including China and India	- NPEOs were detected in fabric of 61% of the 82 articles investigated, with concentrations ranging from 1.2 to 17000 mg/kg - Phthalates were detected in sections of printed fabric from 33 of 35 articles investigated, with total phthalate concentrations ranging from 5.6 110000 mg/kg
Greenpeace 2014[97]	25 countries across the world, including China and India	- NPEOs detected in fabrics from 12 of 27 articles, with concentrations range 1.7 to 760 mg/kg - Phthalates detected in sections of printed fabric from all 5 articles investigated, with total phthalate concentrations ranging from 4.1 to 48 mg/kg - At least one per- or polyfluorinated chemical (PFC) was detected in each of the five articles tested. Total ionic PFC concentrations wereranging from 2.52 to 16.9 mg/kg - Antimony concentrations in 3 articles investigated the fabrics ranged from 54 to 117 mg/kg
Gremmel et al. 2016[98]	Germany	- In all the analyzed outdoor jackets, 23 PFASs varied in a range from 0.03 to 719 µg/m^2
Xu et al. 2017[99]	Albany, New York, USA	- Bisphenol A and Bisphenol S occurred in 82% and 53% of the textile samples, respectively, and at mean concentrations of 366 and 15 ng/g - Benzophenone-3 (BP3) occurred in 70% of the samples at a mean concentration of 11.3 ng/g
Freire et al. 2019[100]	Spain	- BPA was present in 91% of socks for infants and young children at concentrations ranging from <0.70 to 3736 ng/g - Ethyl-paraben was found in 100% of socks, followed by methyl- and propyl-paraben
Li et al. 2019[101]	Harbin, China	- Median concentration of the total phthalates in 24 infant cotton clothing was 4.15 µg/g, with DEHP found to be the dominant phthalate
Tang et al. 2020[102]	Seven Asian countries (China, South Korea, India, Indonesia, Cambodia, Bangladesh, and the Philippines)	-Phthalates were prevalent in all samples of preschool children clothing, in the concentration range 2.92–223 µg/g -Bis(2-ethylhexyl) phthalate, di(isobutyl) phthalate and di-*n*-butyl phthalate were the most abundant phthalates measured

Annexure II: Global regulations on chemicals in textiles

Chemicals	EU	USA	China	India	Indonesia
PFAS	-PFOS restricted under the POPs Regulation -PFOA and its precursors are currently restricted under the REACH regulation, including their presence in products made or imported into the EU -A number of other PFAS are on the REACH list of Substances of Very High Concern	->1300 PFAS compounds and chemicals identified in the Toxic Substances Control Act (TSCA) US EPA Inventory as of April 2021 -US EPA issued a "significant new use rule" (SNUR), to restrict any new useof PFAS by manufacturers.	-Adopted voluntary initiativesuch as "Technical Requirement for Environmental Labeling Products: Textile Products" aimed at environmental labeling of products containing PFAS (PFOA and PFOS) -PFOS is on the list of severely restricted toxic substances under Chinese REACH	-Does not have a regulatory mechanism or framework for the use of PFAS -Although a signatory to SC, it rejected the inclusion of PFOS and any other PFAS chemicals on its global restriction list	-The Ministry of Industry includes the obligation to acknowledge PFOS concentration in textile production processes for companies to be labelled as green textile industry standards -The National Standard Body have released standard on PFOS and PFOA monitoring for several products
NP and NPEOs	- NP and NPEO are covered by Annex XVII (entry 46) to the REACH Regulation - Textile articles expected to be washed in water during their normal lifecycle, in NPEO concentrations equal to or greater than 0.01% by weight of that textile article or of each part of the textile article shall not be placed on the market	- NPEOs have been added to the list of toxic chemicals subject to reporting under Emergency Planning and Community Right-to-Know Act and Pollution Prevention Act	-Though no regulations addressing manufacture, use and release exist, NPs have been added to the list of severely restricted toxic substances under Chinese REACH	-In 2009, NP prohibited in cosmetic products, but no regulation on its use in surfactants or other consumer products	Not available

Chemicals	EU	USA	China	India	Indonesia
decaBDE	-prohibition and/ or restriction of decaBDE as a substance, constituent of substances, in mixtures and articles effective from 2019 under REACH - It is on the Candidate List of substances of very high concern (SVHCs) for authorisation since Dec 2012	-All manufacture (including import), processing, and distribution in commerce of decaBDE, or decaBDE-containing products or articles (e.g., curtains), with some exclusions is prohibited	-Included in the draft plan for new chemical pollutants management, which includes banning the production, processing, use, import and export of chemicals in phases by 2025 -Included in the restricted in consumer products under Chinese REACH	-No specific policy for decaBDE -According to E-waste (Management) Rules, 2016, new electrical and electronic equipment and their components or consumables or parts should not contain polybrominated biphenyls and polybrominated diphenyl ethers beyond a maximum concentration value of 0.1% by weight in homogeneous materials	Not available
Organotin Compounds	-Organotin compounds are restricted in textiles under REACH and shall not exceed 0.1% by weight of tin in consumer products or part of a consumer product	- American Apparel & Footwear Association (AAFA) has included organotin compounds in its Restricted Substances List, which provides information on regulations and laws that restrict or ban certain chemicals and substances in finished home textile, apparel, and footwear products around the world	-Included in the restricted chemicals in consumer products under Chinese REACH	-Indian Standards for Organic Textiles (ISOT) developed under National Programme for Organic Production (NPOP) has included OTCs in prohibited substances during textile processing	Not available

Chemicals	EU	USA	China	India	Indonesia
Phthalates	-Restricted under EU REACH in textiles, clothing, related accessories and footwear at concentrations higher than 1000 mg/kg (individually or in combination)	-The Consumer Product Safety Improvement Act (CPSIA) restricts phthalates to 0.1% in children's products, including children apparel and sleepwear	-Total amount of DEHP, BBP, DBP in childcare articles should not be more than 0.1% -Included in the restricted list of chemicals under Chinese REACH	-Draft Chemicals (Management and Safety) Rules 2020, Indian Government has listed almost 15 phthalates such as DEHP, DiDP, DiBP, BBP, DiOP, DiNP, etc. under Schedule-II list of priority substances	Not available
BPA	- BPA is included in the Substances of Very High Concern Candidate List under REACH regulation. However, only textile products being granted the EU Ecolabel are prohibited to contain excessive BPA	-US FDA has deauthorized use of BPA for baby bottles, sippy cups, and epoxy resins packaging for infant formula. However, at present, there are no restrictions on BPA in textiles	- Banned the use of BPA in the production of baby nursing bottles. However, at present, there are no restrictions on BPA in textiles -Included in the restricted list of chemicals under Chinese REACH	-Currently India has no regulatory framework covering BPA, apart from BIS standards for baby feeding bottles and sippy cups where use of BPA is banned	-No regulations on BPA, including in food-contact plastics
SCCPs	-Restricted under the POPs Regulation -A regulatory limit of 1500 mg/kg in consumer products and 1% in other chlorinated paraffin formulations -Included in the EU list of Substances of Very High Concern under REACH	- Listed as extremely hazardous substances by US EPA -EPA's Significant New Use Rule (SNUR) under the Toxic Substances Control Act (TSCA) covers SCCPs	-Included in the draft plan for new chemical pollutants management, which includes banning the production, processing, use, import and export of chemicals in phases by 2025 -Included in the restricted list of chemicals under Chinese REACH	-No regulation and legislation for SCCPs in India to control its uses and distribution over the market	Not available

Chemicals	EU	USA	China	India	Indonesia
Dyes	-Appendix 8 of REACH lists 24 kinds of azo dyes (aromatic amine compounds) considered carcinogenic or otherwise harmful to humans -Appendix 9 of REACH lists additional azo dyes that are restricted when found in a concentration greater than 0.1% by weight in substances or mixtures used for coloring textiles or leather	-No specific regulations that explicitly restrict azo dyes. Instead, various aromatic amines that cleaved from azo dyes are restricted or banned -Some U.S. states have their own regulations for certain aromatic amines which may be derived from azo dyes. These include California's Proposition 65, Washington's Children's Safe Products Act, and Vermont's Act 188 Chemical Disclosure Program for Children's Products	-Azo dyes releasingspecific amines (under certain conditions) are restricted. The amount of a banned amine that can be detected in the finished articles is limited to 20 mg/kg	-Handling of a total of 112 azo and benzidine based dyes is prohibited under the provisions of the Environment (Protection) Act, 1986, including in imported textiles and clothing	-National Standard of Indonesia requires that dyes containing banned amines listed in amino compound group III (MAK Germany) should not be used on fabrics for babies and children clothing

H2 (Ground Floor),
Jungpura Extension,
New Delhi - 110014
India
Tel: 91-11-24328006, 24320711
Fax: 91-11-24321747

https://www.instagram.com/toxics_link/
https://www.facebook.com/toxicslink
https://twitter.com/toxicslink
https://www.youtube.com/user/toxicslink2012
www.toxicslink.org