Fashion DIET

Societal Health Impact of Textile and Clothing Consumption

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ТРАКИЙСКИ УНИВЕРСИТЕТ
СТАРА ЗАГОРА

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Learning Objectives

After this lecture you should be able to:

- Explain the concept of human ecology / human compatibility.
- Define the core impacts of skin-clothes and textiles on consumers' health.
- Distinguish the physical and chemical hazards of textile consumption.
- Categorise and assess hazardous textile chemicals.
- Differentiate health risks regarding dermatitis, direct and indirect hazards.
- Exemplify pros and cons of sustainable textile use and care in terms of a healthier lifestyle.
- Reflect and reason consumer behaviour and sustainable impact on society and consumers' health.

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Follow-up on Fashions' Fancy Functionalities

- Consumers got used to functionalities of garments like special prints, water-repellent fabrics, non-iron or oil-, soil-, dyestuffs and pigments, crease resistant and anti-shrinking agents.
- Such functionalities result through the treatment of raw materials or finishing activities such as bleaching, dyeing, printing, finishing (easy-care, impregnating), softening and coating, etc. by various chemicals.
- However, some chemicals pose health risks that cannot be ruled out.
- The risks of chemicals associated with a product are often spread over several countries.

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Fabric Finishing - a Combination of various Chemical or Mechanical Processing Stages

- *Pre-treatment*: helps to eliminate sizing agents, oils, waxes, seed hulls, soils, pectin and other impurities (and pesticides), while improving whiteness and feel of the fabric. A typical pre-treatment process includes desizing, scouring and bleaching.
- *Dyeing and printing*:
  dyeing - coloration by various dyestuff classes and dyeing processes.
  printing - a controlled placing of defined areas of colour onto a substrate.
- *Finishing*: usually the last stage of fabric processing where textiles are given improved or additional properties for their intended end use, e.g. crease resistance, easy care, waterproofness, flame resistance, softening and anti-microbial finish etc.
  Finishing requires a combination of various physical and/or chemical processes.
- *Coating*: application of a layer of natural or synthetic polymers to one fabric side.
- *Lamination*: superimposition and bonding of two or more fabrics, or a fabric with paper, film or foam.

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What Western Societies Know about Health Impacts of Textiles and Clothing Consumption

- The media have distributed many examples of *physical hazards* associated with textile and clothing manufacture including fire risk, building construction, noise, temperature, humidity, unsafe machinery, and dust.
- In addition, worldwide environmental problems associated with the textile and clothing industry have also been disclosed, mainly water pollution caused by the discharge of untreated effluent or potentially toxic substances, especially during processing. Thus, supported by scientific literature consumers are intuitively aware that there are *adverse health effects of chemical substances* mainly related with human exposure in textile manufacturing textile processes (*production ecology*).
- However, information about the exposure of consumers and potential human health risks during consumption are much more limited. The lecture therefore focuses on the *human compatibility*, the interrelation of humans (in particular: consumers) with their animate/inanimate environment.

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Chemical Substances in Textile Articles

Chemicals play an inevitable role in all processes involved in textile production starting from cultivation of raw material to finishing of the end product (Rovira & Domingo, 2019).

They can be categorised in:

- functional (or effect) substances
- auxiliary substances
- non-intentionally added chemicals (contaminants, degradations)

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Chemical Substances in Final Articles

Substances used in the manufacture and finishing of textiles *can remain in the final product*, intentionally or unintentionally, but it is difficult to know exactly which substances are contained and to what concentration levels since the supply chains are long and complex with a global span. Information regarding chemical substances in textiles therefore often decreases when going down the supply chain (Posner & Jönsson, 2014).

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Various Modes of Exposure to Textile Chemicals

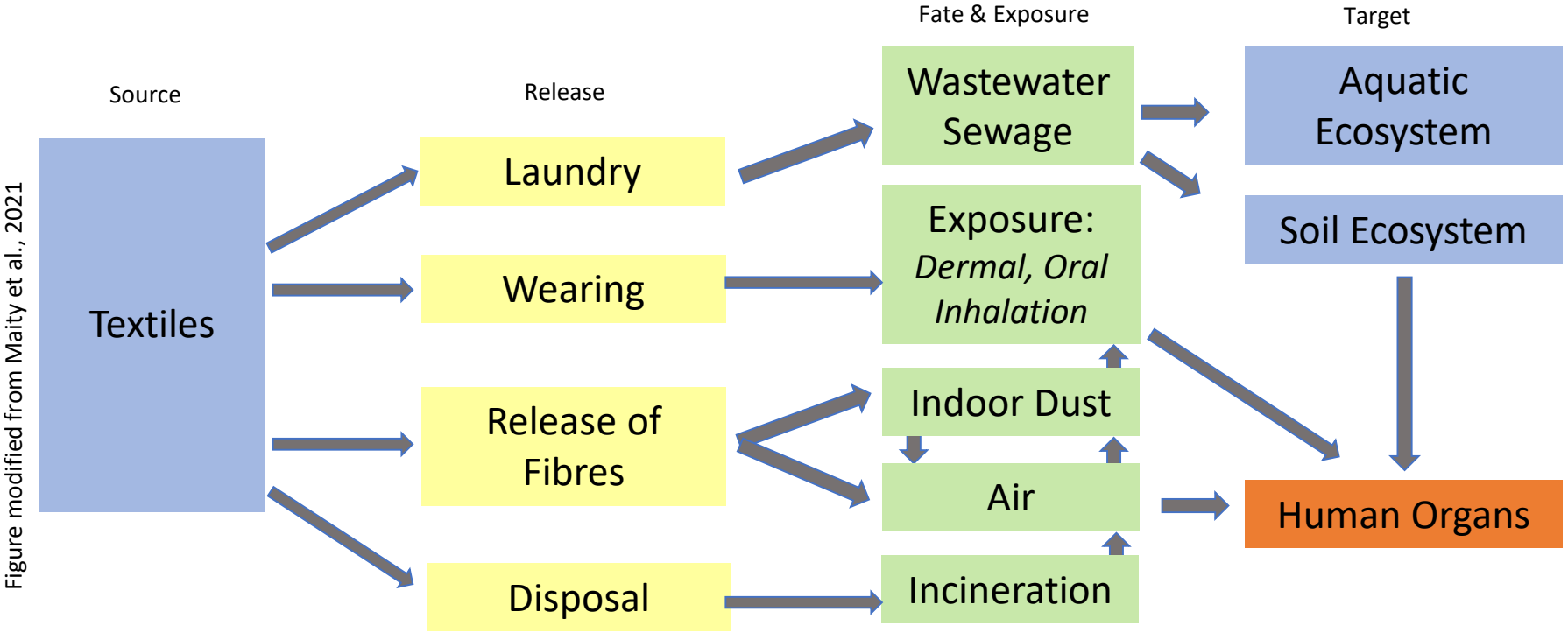

Figure modified from Maity et al., 2021

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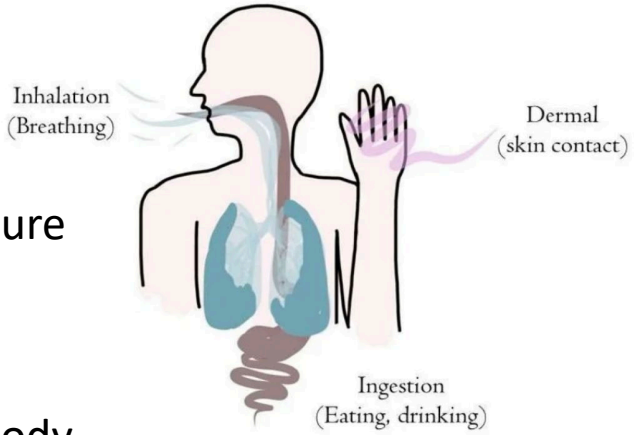
Exposure Routes for Textile Chemicals

- In general, humans are exposed to toxicants mainly through the diet (food and drinking water) and breathing (air pollution), i.e. via ingestion and inhalation.
- However, *for textile chemicals dermal exposure predominates* as everyday use of textiles leads to exposure of chemical content in textiles to wearers (Rovira & Domingo, 2019).
- In addition, the skin is the largest organ of the human body, accounting for approximately 12–15% of body weight.
- Skin exposes a large area to clothes (appr. 85%) and it is permeable to molecules with specific size and polarity.



Shah, 2015

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Inhalation Exposure

Chemical exposure through inhalation is mainly relevant to retail workers handling new textile articles and/or in poorly ventilated indoor areas with large quantities of textiles. Warehouses for textile articles, clothing stores, furniture stores and public facilities with a lot of textile furnishing are examples of places where inhalation of chemical substances from textiles might be a problem for human health (Robert et al., 2021).

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Ingestion Exposure

Oral exposure by mouthing of textiles is normally a minor pathway except for small children who often put things in their mouths and for which this mouthing behaviour may lead to significant exposures. Due to the mouthing behaviour of small children and the fact that they often stay close to the floor, dust is in some cases an important source of exposure for children.

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Dermal Exposure

Textiles especially skin-clothes comprise the largest total area of all surface areas in the indoor environment due to everyday use (Lee & Choi, 2009). In addition, home textiles like bed linen contribute to human exposure.

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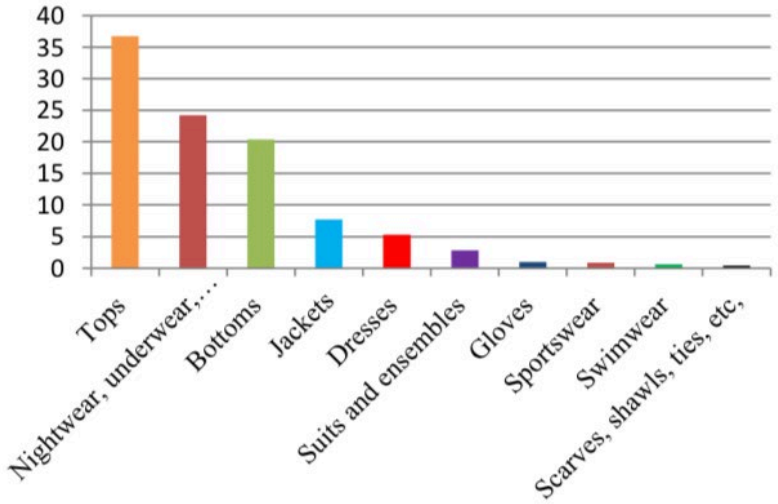

Consumption of skin-clothes in the EU in percentage breakdown (Beton et al., 2014)

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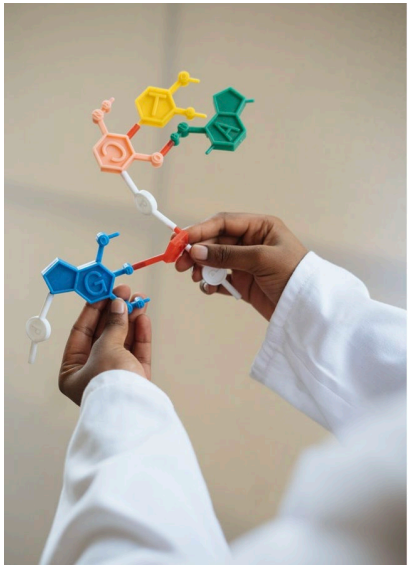
Exposure to Hazardous Substances in Branded Textile Products

Brigden et al. (2012) reported on the presence and in some cases high concentrations of hazardous chemicals (nonyl phenol, carcinogenic amines, and phthalates) *in branded textile products on sale in 27 countries*. These results suggest the necessity of developing robust policies to force the elimination of such chemicals from manufacturing processes of textiles and in the finished products.



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Evaluation of Control Measures for Hazardous Substances

There are important control measures for many hazardous compounds in the EU (like REACH*). However, the continuing relocation of textile production to countries with fewer environmental restrictions and work standards, and the complex raw material supply chains as well as the large numbers of operators, involved in the different production steps, make a strict control on the presence of some toxic chemicals in textiles in general, and in clothes in particular, indeed very difficult.

Washout Effect during Laundry

- Luongo et al. (2014) detected the carcinogens quinoline and benzothiazoles in garments taken from different shops in Stockholm, Sweden. *Considerable amounts of hazardous compounds remained in the clothes even after ten times of washing:* The average decrease in concentration for benzothiazoles was 50% after ten times of washing, while it was around 20% for quinolines.

- *Residual concentrations of some substances can remain and can be released during the use by the consumers,* although most chemicals added during the processes of manufacturing clothes are rinsed out (Luongo et al., 2016).

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Textile Chemicals – Exposure, Uptake, Impact

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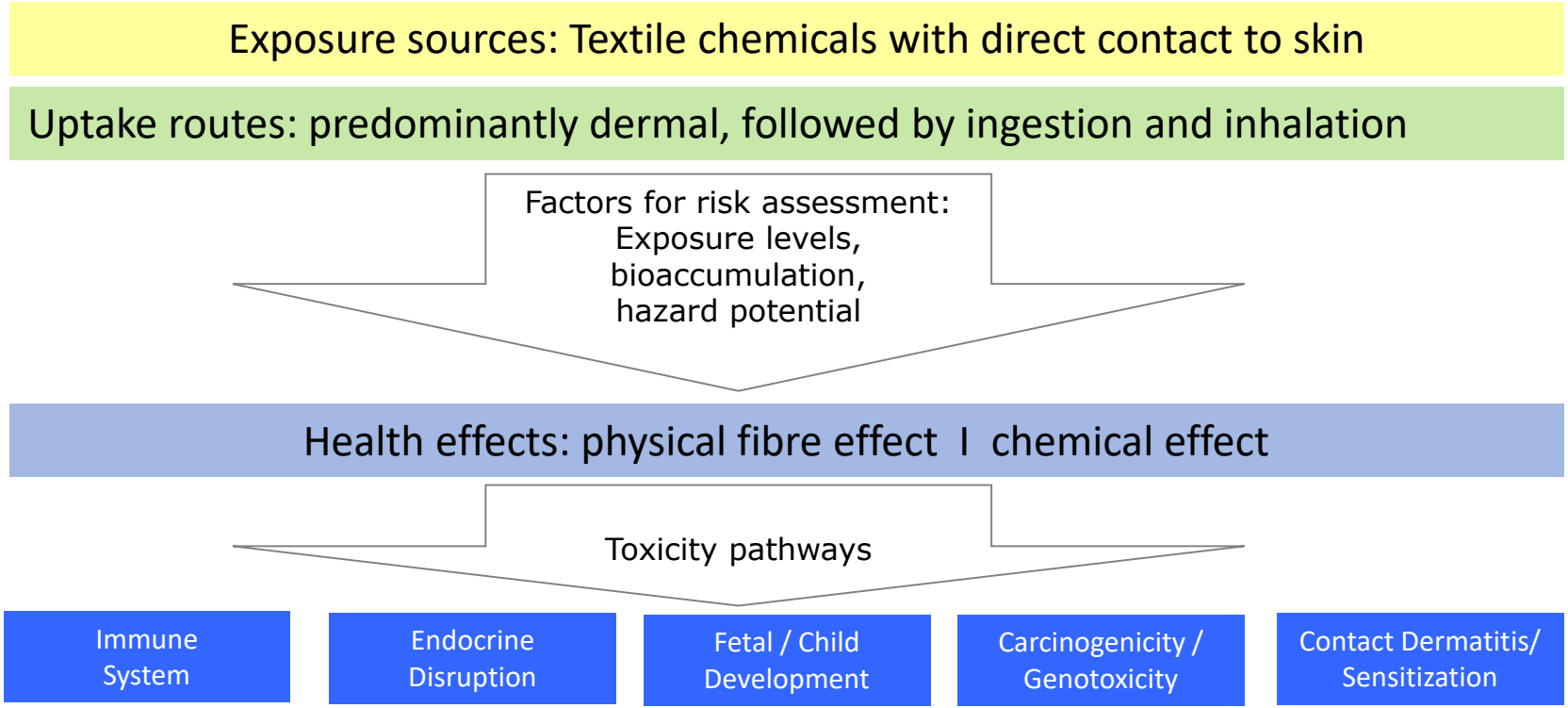

Figure modified from Wright & Kelly, 2017

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Textile Chemicals – Toxicity Pathways

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Immune System	Toxic effects on the immune system, which defends the body from harmful agents.
Endocrine Disruption	Substances with hormone like activity, also interfering with gene-regulation.
Fetal / Child Development	After the embryonic stage, the fetal stage begins and a baby is called a fetus. This stage runs from the 11th week until birth.
Carcinogenicity / Genotoxicity	Genotoxicity describes the property of chemical agents that damage the genetic information within a cell. Carcinogenicity: Mutations which may lead to cancer.
Contact Dermatitis/ Sensitization	Dermatitis is a general term that describes a common skin irritation. Sensitization is the action or process of making sensitive or hypersensitive and leads to an allergic sensitization of the skin / of a being.

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Two Kinds of Contact Dermatitis from Skin Sensitizing Substances in Textile Articles

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1. Fibre effect

Irritant dermatitis often relates to wool allergy, where protruding elastic fibres (wool) bend into the skin, thus leading to a local reddening. In Germany up to 2% of all contact dermatitis cases are due to textiles (BfR, 2012).

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Two Kinds of Contact Dermatitis from Skin Sensitizing Substances in Textile Articles

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2. Chemical effect

Allergic dermatitis a skin inflammation with redness, rash and oedematous lesions, caused either by skin sensitizing chemical substances, added to or present in the textile. 214 sensitizing textile chemicals of concern are known. *Textile disperse dyes and formaldehyde* are most commonly reported to cause allergic dermatitis, whereas dyes and formaldehyde make up 3.6% prevalence among consecutive patients, despite new regulations (BfR, 2012).

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Health Effects due to Hazardous Chemicals

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Health effects caused by exposure to toxic chemicals fall into two time categories:

1. **short-term effects**, having a relative quick onset after brief exposure to relatively high concentrations. The effect may be either local (skin, eyes) or systemic (susceptible organs).

2. **long-term effects**, occurring after a long period of time between exposure and injury, e.g. repeated exposures to low concentrations of material (chronic exposure).

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Categories of Hazardous Chemicals

10% of 2400 textile-related substances are considered of potential risk to human health. These can be assigned to four substance categories (Posner & Jönsson, 2014):

Dyeing and printing: sensitizing and allergic dyes, disperse dyes, basic and acid dyes, direct dyes, water-insoluble vat dyes, reactive dyes and azo dyes.

Pesticides:

used to cultivate cotton.

Heavy metals: cadmium, lead, mercury and chromium.

Regulated chemicals: alkylphenols, phthalates, brominated and chlorinated flame retardants, perfluorinated chemicals, chlorobenzenes, chlorinated solvents, chlorophenols, short-chain chlorinated paraffins.

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Linkage Effect along the Textile Value Chain

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*“When it comes to textile chemicals, the impact of our consumer behaviour seems to strike back.” **

That is why we have regulations, ecolabels and research focussing on human health risks due to exposure to inorganic and organic chemicals from textiles (Rovira et al., 2019).

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EU Regulations Governing Chemicals

- Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).
- Regulation (EC) No 1272/2008 on classification, labelling and packaging of substances and mixtures amending and repealing Directive 67/548/EEC and 1999/45/EC, and Regulation (EC) No 1907/2006 (CLP).

REACH includes several restrictions of hazardous chemical substances. However, REACH was not specifically designed to account for chemical substances in textiles. REACH requires companies to obtain knowledge about the hazards posed to health and the environment by their chemical substances. Manufacturers and importers have to register substances manufactured or imported in quantities of more than one tonne per manufacturer or importer per year to the European Chemical Agency. Many functional substances used in the textile and fashion industries in the EU might not fall under the obligation for registration since their quantity does not exceed one tonne. A lack of information about the use of chemicals affects the quality and risk assessment.

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Voluntary Initiatives – Ecolabels and RSL

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Eco-Labels

The aim of voluntary textile labels is to guide professional buyers and consumers in their choices of textiles that have less negative impact on health and environment. The consumers' choices are important when it comes to encouraging textile manufacturers to provide more eco-labeled products. In 2022 the vast majority of EU Ecolabel product groups have witnessed an increase in both the number of licences and products (EU Ecolabel Factsheet, 2022).

Restricted Substances Lists

In addition to the voluntary labels, many textile companies require their suppliers to comply with so called Restricted Substances Lists. Proactive textile companies thus use either eco-labels or their own list containing hundreds of hazardous substances which are not regulated in current EU-legislation, such as in REACH, and thus go way beyond current legislation.

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Can the Responsibility be passed on to Voluntary Initiatives?

- Labels are intended to provide information for consumers at the point of purchase. Labels disclosing the fibre content of clothing and permanent care labels are both required by law.
- According to the media platform ‘Textile Standards & Legislation’ there are about 100 international standards and labels. Only some of these aim to ‘guide’ professional buyers and consumers in their choices of textiles that have less negative impact on health and environment. A selection is given below:

Blauer Engel - Textilien

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A ‘Harmless to Health’ Label for End Consumers

- The Oeko-Tex Standard 100 is a globally uniform testing and certification system for textile raw materials, intermediate and end products at all stages of production. Launched in 1992, to date 65,000 certificates have been issued (Ecolabel Index, 2022)
- The certification covers multiple human-ecological attributes, including harmful substances which are prohibited or regulated by law, chemicals which are known to be harmful to health, but are not officially forbidden, and parameters which are included as a precautionary measure to safeguard health.
- A tested textile product is allocated to one of the four Oeko-Tex product classes based on its intended use (babies, with and without direct contact to skin, decoration material). The more intensively a product comes into contact with the skin, the stricter the human ecological requirements it must fulfil.

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Find out about the Label – Recommendation

- Labels in general can help you to make better decisions about which products you want to buy and which you don’t.
- When non-sustainable companies see their competitors adding eco-labels, those non-sustainable companies become more motivated to be more eco-friendly. This competition between businesses could lead to a serious industry shift toward more sustainable practices.
- The ‘Verbraucher Initiative e. V.’ (Consumer Initiative Association) classifies most of the common quality labels and ranks them on a four-point scale. On this scale, the Oeko-Tex Standard receives an overall rating of "recommendable", which corresponds to the second-best rating.
- In its textile guide, Greenpeace (2016) points out that the Oeko-Tex Standard 100 covers many important potentially harmful substances, but that other quality seals are more recommendable due to significantly stricter award criteria and processes.

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Find out about the Label – Critics

- *Random sample tests*: During product checks in the retail trade, products with the Oeko-Tex label are checked for conformity with the test sample, but this only applies to about 20% of labelled products. Hence, market products in Europe still may contain harmful substances (see Brigden et al., 2012).
- *Misleading*: The word ‘Oeko’ can be misleading and suggests that certified products are ecologically produced textiles made from natural fibres.
- *Monitoring gaps*: Laboratory tests are only run with samples that manufacturers sent prior to the date of delivery, so there is the possibility to make a false self-declaration of conformity that the pre-sent sample matches the quality of the products manufactured and distributed for the retail trade. In addition, bribery can not be excluded, e.g. when manufactures are facing company audits.
- *Lack of independence*: The manufacturers of the products and the testing and certification bodies are not sufficiently separated from each other in legal and economic terms.

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Most Harmful Chemicals in Textiles

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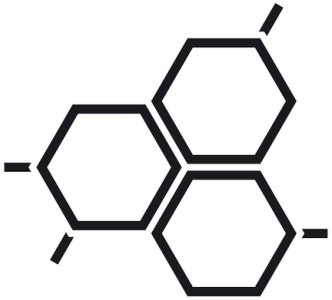
Brominated Flame Retardants

Abdallah & Harrad (2018) provided the first experimentally-based assessment of dermal uptake of BFRs via contact with indoor dust and flame-retarded furniture fabrics. Using a 'realistic' exposure scenario they found a substantial uptake from furniture fabrics, exceeding the overall adult intake of pentabrome-diphenylether PBDE estimated previously via other exposure pathways: PBDE penetrates the human skin barrier and reaches the blood, where it becomes bioavailable. Thus, adult dermal absorption of PBDEs from contact with a flame-retarded sofa fabric is approximately two orders of magnitude higher than that via contact with indoor dust.

Tao et al. (2018) found that room attendants in hotels in Wuhan, China, are significantly more exposed to organophosphate flame retardants.



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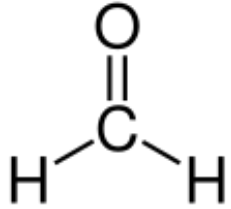
Formaldehyde

- Formaldehyde is commonly used in several textile production processes: It allows for better saturation of some dyes and inks used to colour textiles and make textiles less prone to shrinking and more crease-resistant, hence their use in wrinkle-free clothing (easy-care finish). Formaldehyde is also used on permanent-press textiles and on outdoor textiles, to prevent mildew and increase stain resistance.
- Formaldehyde is volatile. In case of skin contact, it must be regarded as an important contact allergen which causes textile dermatitis.
- According to the Regulation (EC) No 1272/2008 on the classification, labelling and packaging of substances and mixtures, formaldehyde is classified as a hazardous substance with carcinogenic properties.



structural formula of formaldehyde

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Formaldehyde Found in Clothes

- The European survey on the release of formaldehyde from textiles analysed a total of 221 samples. 22% of the 127 analysed samples contained a level of formaldehyde higher than the Ecolabel limit. Domestic washing decreased the formaldehyde content by 40% (Piccinini et al., 2007).
- Novick et al. (2013) analysed 20 cloth items and detected formaldehyde only in 3 of them. However, levels of 2 out these 3 detected items (3172 and 1391 ppm) were 40-fold higher than the concentrations established by international textile regulations. Washing and drying reduced formaldehyde concentrations between 26% and 72%.

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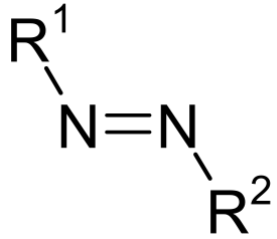
Azo and Disperse Dyes

- Problems with dyes (e.g. bad colour fastness) arise when dying procedures are not carried out under optimal conditions or the dye is not suited for the specific material.
- Dyes are the most important group of substances used in textiles when it comes to possible health risks. Some have mutagenic effects.
- **Disperse dyes** are small, insoluble substances and a sub-group of azo dyes. They are preferably used for dyeing hydrophobic polyester and acetate fibres. Together with their solvents (e.g. carriers) disperse dyes are easily absorbed by the skin. Health risks: allergenic and carcinogenic.
- Of the 4,000 or so dyes listed in the Colour Index, about one half are **Azo dyes**, some of which are manufactured on the basis of carcinogenic amines. After intake into the human body, azo compounds may break down and then form the corresponding dangerous aromatic amines from which they have been synthesized. Currently, there are more than 2,000 azo dyes in the market used to dye cotton, silk, wool, leather, viscose, and other synthetic fibres. Some aromatic amines cause cancer, allergies and genotoxicity.



structural formula of azo dyes

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Dyes - Market Surveillance and Regulation

- Crettaz et al. (2019) found in 25% of all samples taken from the Swiss market hazardous non-regulated aromatic amines as cleavage products of azo dyes in clothing textiles.
- Brüschweiler et al. (2014) investigated the occurrence of azo dyes of skin-contact clothes in the Swiss market: From 153 samples, 22% contained non-regulated aromatic amines.
- Regulation: Appendix 8 of REACH lists 24 kinds of aromatic amine compounds considered carcinogenic or otherwise harmful to humans. Specifically, any azo dye that, under testing conditions referenced in Appendix 10, produces 30 mg or more of the above mentioned aromatic amines per 1 kg of dye must not be used in any textile or leather product that comes into direct and prolonged contact with the human skin or the mouth.
- In October 2019, three carcinogenic disperse dyes were included within REACH Regulation (EC) No.1907/2006 Annex XVII.

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Direct and Indirect Toxic Effects

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Direct toxic effects:

Azo dyes and fragrances that may cause cancer, contact dermatitis, allergies or initiate developmental effects.

Endocrine disruption, nanomaterials, combination effects of 2 chemicals, combined exposure from different sources and via different exposure routes, special sensitivity of children to chemical exposure, e.g. by ingestion of indoor dust (Posner & Jönsson, 2014).

Indirect toxic effects:

As textile-related chemicals are ecotoxic, persistent in the environment and bio-accumulative (in the aquatic food chain), there are also indirect risks to humans, e.g. exposure via dietary routes. In the EU, the laundry releases additional 2-22 tons of chemicals annually into the waste water that may come into contact with consumers (Šajn, 2019).

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Phthalates

- Phthalates, a wide range of chemical compounds, are mainly used as plasticizers in plastics (especially PVC) to increase softness and flexibility. Often the final consumers of textiles with printed PVC are children.
- Hazard potential: endocrine disrupting compounds.
- Pedersen & Hartmann (2004) analysed phthalate content in children clothes. Phthalates were detected in all the garments tested (19 samples), with levels between 1.4 mg/kg and 200,000 mg/kg (around 20% of the weight of the sample).
- In turn, Negev et al. (2018) found phthalate (mainly DEHP and DINP) levels in nylon sheets, crib mattress and diaper-changing mats above 0.1% (by mass) above the standard set by EU Commission Regulation (EC No. 552/2009).

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Benzothiazoles and Benzotriazoles

- Use: Benzothiazoles and benzotriazoles are used in a wide range of textile applications, including rubber vulcanisation and corrosion inhibition.
- Hazard potential: genotoxic, endocrine disruptors, may also act as dermal sensitizers.
- Liu et al. (2017) determined the occurrence of benzothiazole / benzotriazole and 7 common derivatives in a total of 79 textile samples, including raw textiles (fabrics) and infant clothing (blankets, diapers and clothing) with elevated concentration.
- These compounds remained in the clothes even after 10 times of washing (Luongo et al., 2016). Highest concentration of benzotriazole (14,000 ng/g) were found in a printed graphic of an infant's bodysuit and in baby socks.

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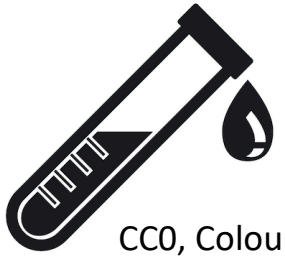
Bisphenols

- Hazard potential: Bisphenols are endocrine disruptors, toxic to reproduction and skin sensitisers.
- Use: Coating and intermediate chemical in the manufacture of dyes and antioxidants.



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Xue et al. (2017) analysed 77 textiles and infant clothing pieces to determine the occurrence of various bisphenols, including bisphenol A and bisphenol S, benzophenones, etc. They included raw textiles, cloth diapers, blankets, and clothing marketed for infants aged < 1 year. The results show that bisphenols occur in 82% and 53% of the textile samples, with mean concentrations of 366 and 15 ng/g, respectively.

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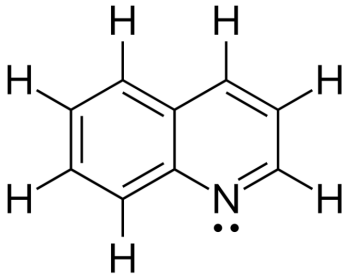
Quinoline

- Quinoline is used to manufacture dyes. The heterocyclic aromatic organic compound has the chemical formula C_9H_7N.
- Quinoline is a colourless hygroscopic liquid with a strong odour.
- Hazard potential: Quinoline is a skin irritant and/or also probable human carcinogen.
- Luongo et al. (2014) detected 29 of 31 samples contaminated with quinoline, up to 1.5 mg in a single garment.



structural formula of quinoline

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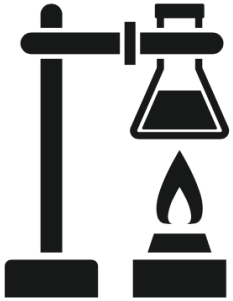
Metals

- Metals are used for many purposes, such as metal complex dye (cobalt, copper, chromium, lead), pigments, mordant (chromium), catalyst in synthetic fabrics manufacture (antimony oxide), synergists of flame retardants, antimicrobials (nanoparticles of silver, titanium oxide and zinc oxide), water repellents and odour-preventive agents.
- Hazard potential: multiple effects on organs incl. neurological impacts, e.g. lower energy levels and functional damage of the brain, lungs, kidney, liver, blood composition and other organs. Long-term exposure can lead to gradually progressing physical, muscular, and neurological degenerative processes that imitate diseases multiple sclerosis, Parkinson's and Alzheimer's disease.



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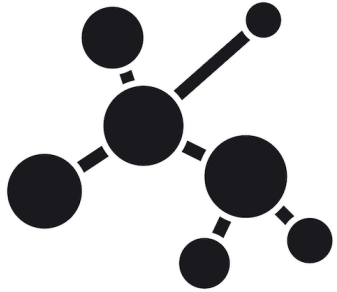
Metals in skin-clothes

Nguyen & Saleh (2017) determined the levels of several metals (Ag, Al, As, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Li, Mg, Mn, Na, Ni, Pb, Sb, Se, Sr, Ti, V and Zn) in 120 samples (63 cottons, 44 nylons and 13 polyesters) of different brands and colours of women undergarments manufactured in 14 countries. It was found that cotton samples were rich in Al, Fe and Zn, while nylon undergarments contained high levels of Cr, Cu and Al. In turn, polyester fabrics contained higher concentrations of Ni and Fe compared to cotton or nylon.



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Recommendations how to Reduce Chemical Hazards

1. **Wash new skin-clothes prior to first wear**
   in order to rinse and remove unbound chemicals
   such as unreacted dyes, additives, flame retardants etc.

2. **Watch for trustworthy textile eco-labels to avoid harmful chemicals**
   e.g. Oeko-Tex, Green Button, Bluesign, Made in Green

3. **Consume reasonably**
   a) prefer pre-washed second-hand clothes
   b) prefer durable and high-quality apparels
   in order to wear them over a longer period of time

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Conclusions

- Consumers are exposed to potentially toxic chemicals mainly through skin-contact textiles or clothes. Contaminations can hardly be assessed by consumers.
- The human health risk of dermal exposure to fabrics is based on the non-negligible presence of various chemicals in some textiles that might lead to potential systemic risks.
- There are important control measures for many hazardous compounds in the EU such as REACH. However, the textile production in countries with fewer environmental restrictions and lower occupational health standards, the complex raw material supply chains as well as the large numbers of operators, involved in the different production steps, make a strict control on the presence of some toxic chemicals in textiles in general, and in clothes in particular, very difficult.
- Until the rise of a federally regulated transparency in the supply chain, voluntary eco-labels allow consumers to make first comparisons among products regarding healthy (and environmentally preferable) products.
- Consuming eco-labelled, pre-washed or second-hand textiles and clothes reduce the chemical hazards due to skin-contact clothes.

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Further Readings

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