Microplastic Fibres and Particles in the Textile Chain – Environmental Impact and Health Effects

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Learning Objectives

After this lecture you should be able to:

- Define the term microplastic, its sources and emissions.
- Define the core impacts of microplastic on the environment and its effects on human health.
- Exemplify pros and cons of a sustainable textile consumption in the context of microplastic.
- Discuss the relationship between producer / consumer in the context of microplastic.
- Reflect and reason your consumer behavior and sustainable impact on microplastic production.
- Exemplify strategies to reduce microplastic.

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Definition of Microplastics and Microfibres

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- *Plastics* are synthetic materials of petrochemical origin, created from polymers, sometimes supplemented with copolymers and/or additives. In general, they have poor water solubility and poor biodegradability.
- *Microplastics:* solid plastic particles < 5 mm.
- *Primary microplastics*: intentionally added to products for specific functions, e.g. cosmetics, pigments and paints.
- *Secondary microplastics*: results from fragmentation of larger plastics due to abrasion or photodegradation.
- *Textile microfibres*: a microplastic sub-group shed during wash cycles.

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Prioritisation of Microplastic Sources and Emissions

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- Secondary microplastic sources with a relatively high score are synthetic fibres (nylon, polyester, polyolefin, and acrylic) from the textile and clothing industry (score 6-7 (same as abrasion of tyres)).
- Plastic debris which consists largely of packaging materials and disposable products is the most important (land-borne) source of microplastic.
- This evaluation is based on a multi criteria analysis by Verschoor et al. (2014) on a scale from 1-10.

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Fast Fashion as a Global Environmental Justice Issue

- *Environmental hazards during production*
  In 2017, the EU produced 7.4 kg of textiles per person while consuming nearly 26 kg. The EU is therefore a net importer, e.g. of textiles made of cotton or polyester, both fibres associated with significant health impacts from the manufacturing and production processes (European Environment Agency, 2019).
- *Occupational hazards during production*
  Includes respiratory hazards due to poor ventilation such as cotton dust and synthetic air particulates (microplastic) (Bick et al., 2018).
- *Textile waste*
  Environmental injustices continue long after the garment is sold. Fast fashion encourages consumers to view clothing as being disposable. EU consumers discard about 11 kg of textiles per person per year.

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Microplastic Contribution of the Textile and Clothing Industry

- Henry et al. (2019) estimated that about 20-30% of the primary source of microplastic pollution is synthetic clothing with respect to the whole life cycle (production-consumption-disposal).
- Boucher & Friot (2017) estimated that of all secondary microplastic in the world's oceans 35% arise from laundry of synthetic textiles.

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Problem: Impacts on Global Ecosystems

Microplastic originates from incorrectly discarded consumer products worldwide. It can be detected in most of the oceans and is absorbed and bioaccumulated by marine animals. It is ubiquitous and has been found in the marine and terrestrial *ecosystems*, including oceans, rivers, air, drinking waters, sediments, and foods, worldwide. In addition, airborne microplastic leads to a fallout to aquatic and terrestrial surfaces (Jiang et al., 2020).

Vice News, YouTube

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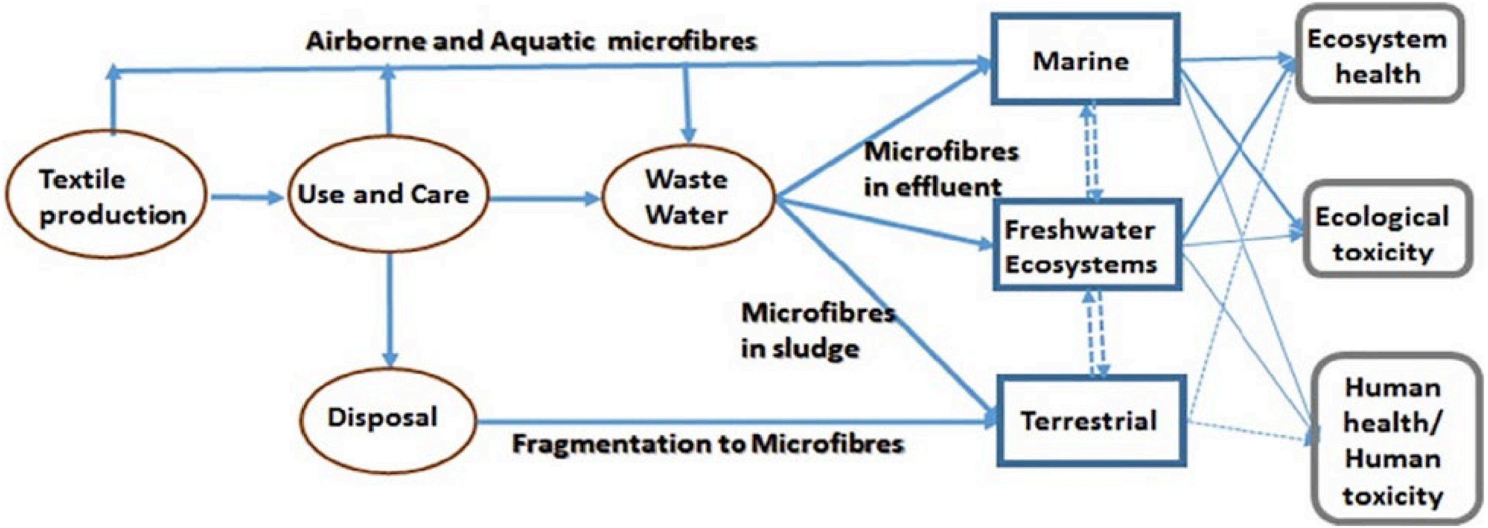
Sites of Release and Impacts on Health and Ecosystems



Henry et al., 2019

Over 95% of plastic particles are retained in the biosolids from the treatment plant. The resulting sludge is often used on agricultural land and the particles are scattered by the wind or transported by rainwater drainage back into the water systems. The main impact is observed in third world countries where most production takes place and wastewater is often discharged unfiltered into waterways.

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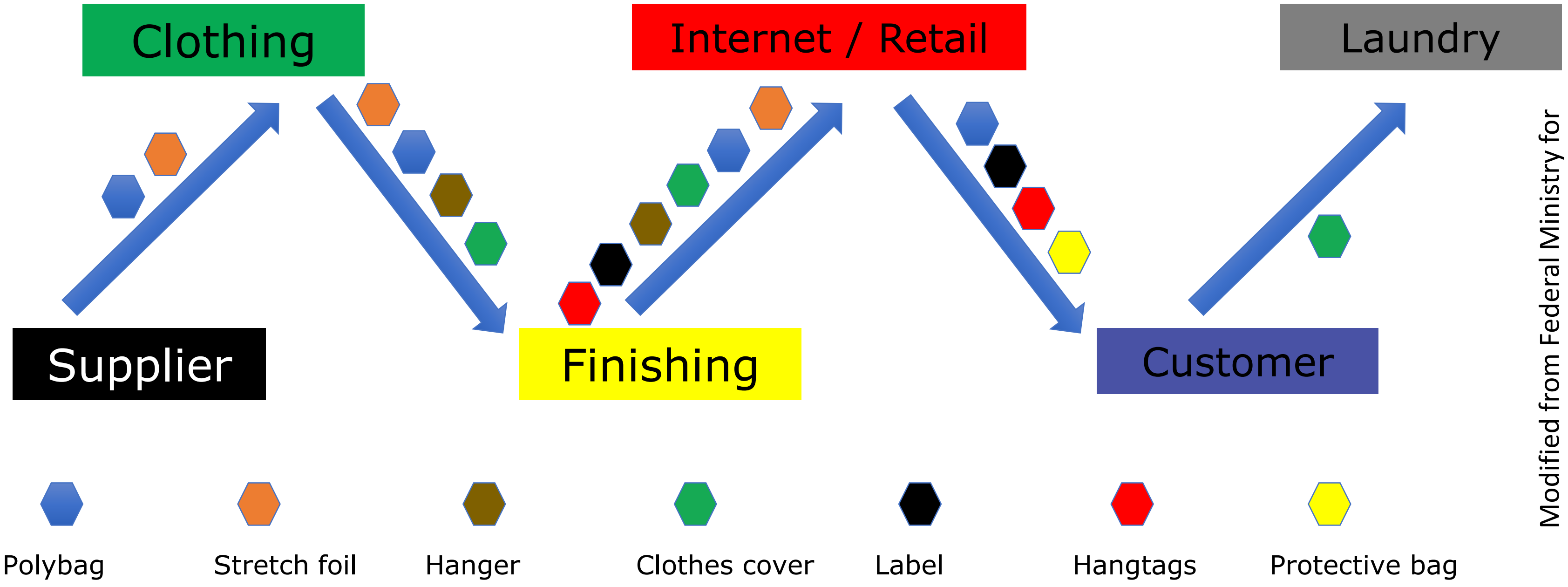
Plastic Packaging along the Textile Supply Chain



Modified from Federal Ministry for Education and Research, 2020

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Beside Production Countries Consumers Contribute to Microplastics

- Each year half a million tons of microplastic and microfibers from textile washing activities are released into the ocean; this is an equivalent to 50 billion plastic bottles (The UN Alliance for Sustainable Fashion, 2020).
- Nizzetto et al. (2016) conservatively estimated that approximately 50% of sewage sludge, including the microplastic release from waste water treatment plants, is applied to agricultural lands in Europe and North America.

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Use and Care in Consuming Countries

- Microplastic pollution caused by *washing processes* of synthetic textiles was discovered to be one of the main sources of primary microplastics. Microfibres < 5 mm released during washing range from 124 to 308 mg per 1 kg of washed fabric depending on the type of washed garment. This corresponds to a number of microfibres ranging from 640,000 to 1,500,000 (Prata et al., 2019).
- It is estimated that about half a million tonnes of plastic microfibres are released into the ocean annually from washing plastic-based textiles (EEA, 2019).
- *Wear and tear* of fibres and clothing is likely to be another major source of microplastics, predominately airborne microfibres.

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EU Regulatory Measures to Tackle the Microplastic Issue

- 2016 OECD Extended Producer Responsibility - EPR
  a stewardship policy targeting corporations marketing consumer goods that holds manufacturers responsible for the post-consumer phase of plastic packaging.
- 2018/2019 EU Microplastic Positioning Paper
- 2019 EU parliament seals ban on throwaway plastics by 2021.
- 2020 EU Green Deal (The Microfibre Consortium, TMC)

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Problem: Health Effects of Microplastics

Once in the environment, microplastic can

- *release* harmful plastic additives and/or
- *adsorb* other environmental chemicals.

These chemicals have been shown to exhibit toxic or endocrine-disrupting effects on living organisms when particles or fibres are taken up (Jiang et al., 2020).

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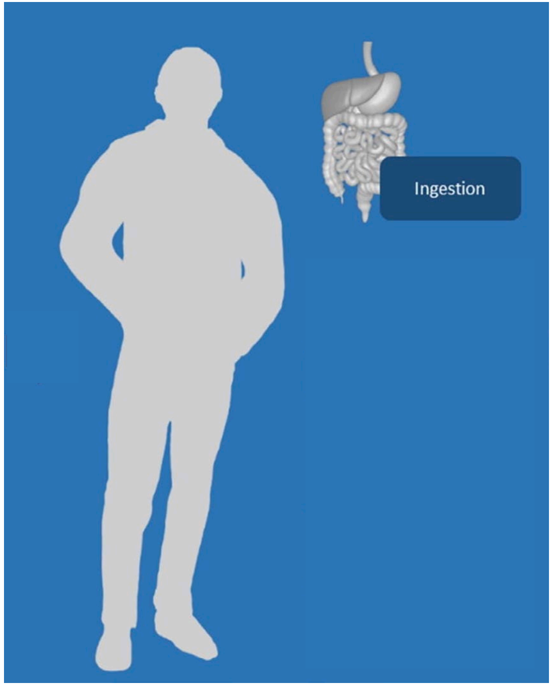
Exposure of Consumers

Food

Microplastics have been reported in a wide range of human food and beverages, incl. tap water. Seafood consumption represents one pathway for human microplastic exposure via ingestion. Over 800 animal species are contaminated with plastic via ingestion or entanglement including marine mammals, fish, invertebrates, and fish-eating birds. Microplastics are transferred up the food web. Microplastic (1–5000 µm) median intake rates are 553 particles/capita/day and 883 particles/capita/day for children and adults, respectively (Mohamed Nor et al., 2021) and 120,000 particles per anno (Cox et al., 2019).



Prata et al., 2019

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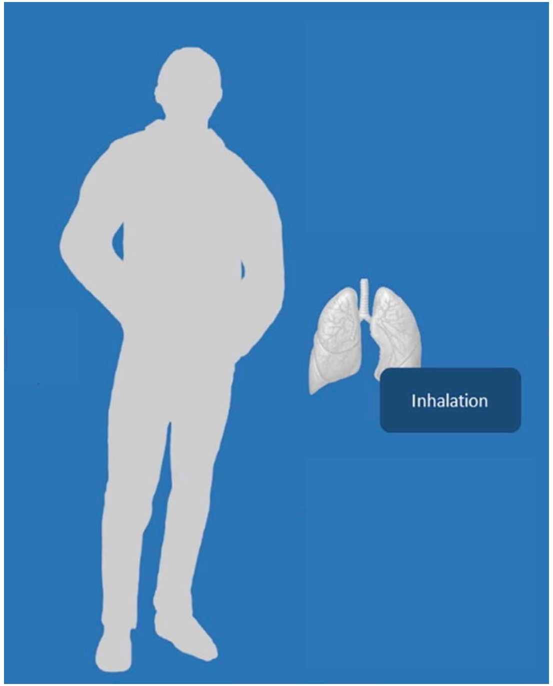
Exposure of Consumers

Inhalation

- Inhalation of microplastics is greater in urban areas and is greater indoors than outdoors, e.g. approximately in Paris 200 microparticles/m^3/day.
- The inhalation of microplastics results mainly from microfiber release by synthetic textiles.
- Particles which are cleared from the airways end in the gastrointestinal tract, and so join with the particles which have come from ingestion (Prata et al., 2019).



Prata et al., 2019

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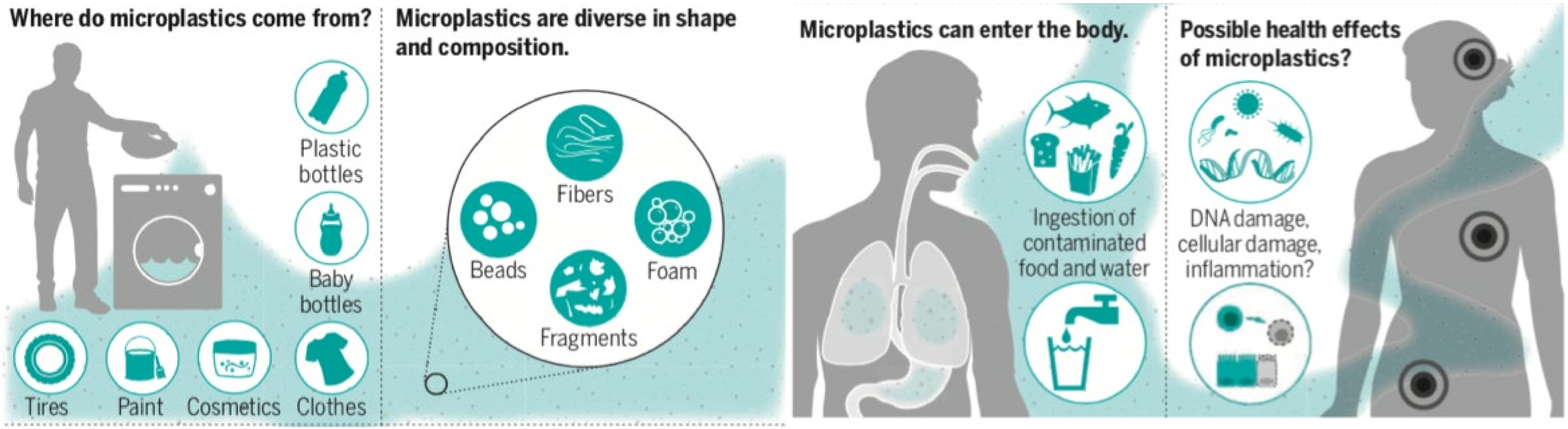
Microplastics and Human Health

Vethaak & Legler, 2021



Microplastics have diverse shapes and encompass a suite of chemical and biological constituents. They can enter the human body through ingestion and inhalation where they may be taken up in various organs and might affect health, for example, by damaging cells or inducing inflammatory and immune reactions (Vethaak & Legler, 2021).

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Overview on Exposure, Uptake and Impact on Human Health

Modified from Wright & Kelly, 2017

Exposure sources	Diet — Microplastics — Environment
Uptake routes	Ingestion — (Dermal) — Inhalation
	Exposure levels Bioaccumulation potential
Health effects & Toxicity pathways	Particle effect I Chemical effect I Microbial effect

- Vector for chemicals
- Disruption of homeostasis
- Local inflammation
- Oxidative stress Genotoxicity
- Translocation into tissues

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Three Mechanisms of Microplastic Toxicity

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Chemical effects

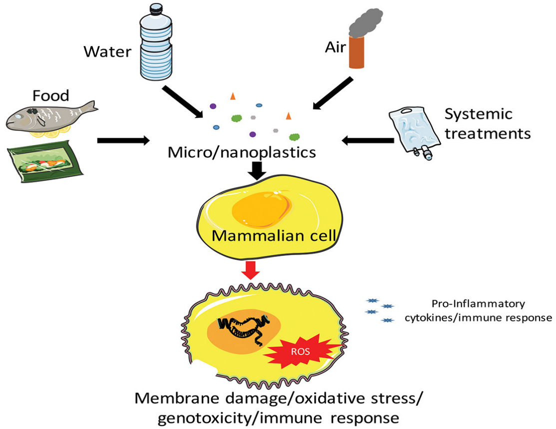
Leaching of chemicals in edible tissues. Chemicals such as

- component monomers,
- endogenous additives,
- adsorbed environmental contaminants.

(Prata et al. 2019).

Physical / Particle effect

Localized toxicity of particles to living cells.



Cell response dependent on plastic size, charge, dose, exposure time, composition & presence of co-contaminants

Biological effects

- Inflammatory responses
- Oxidative stress
- Disruptions of the gut microbiome (dysbiosis)
- Hitchhiker effect of absorbed pollutants
- Size-dependent trans-location across living cells of the gut into the circulatory and lymphatic system (Ramsperger et al., 2020).

Banerjee & Shelver, 2020

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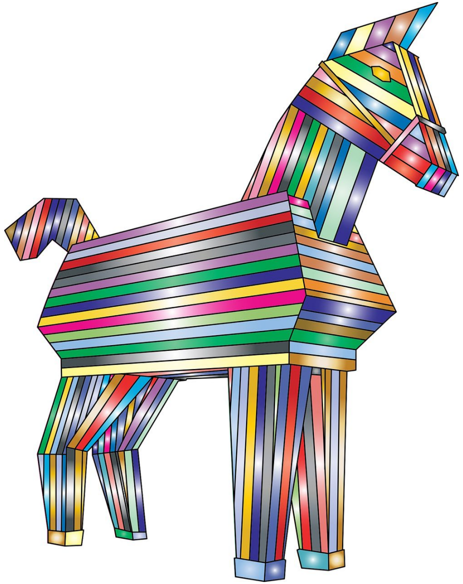
Critical Review:
Linkage Effect along the Textile Value Chain



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"When it comes to microplastics, the impact of our consumer behaviour seems to strike back."

This statement whether microplastics have adverse (toxic) health effects on humans should be questioned by a thorough risk assessment.

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Excursion on Exposure, Toxicity and Hazard - a Risk Assessment Approach for Lay Persons

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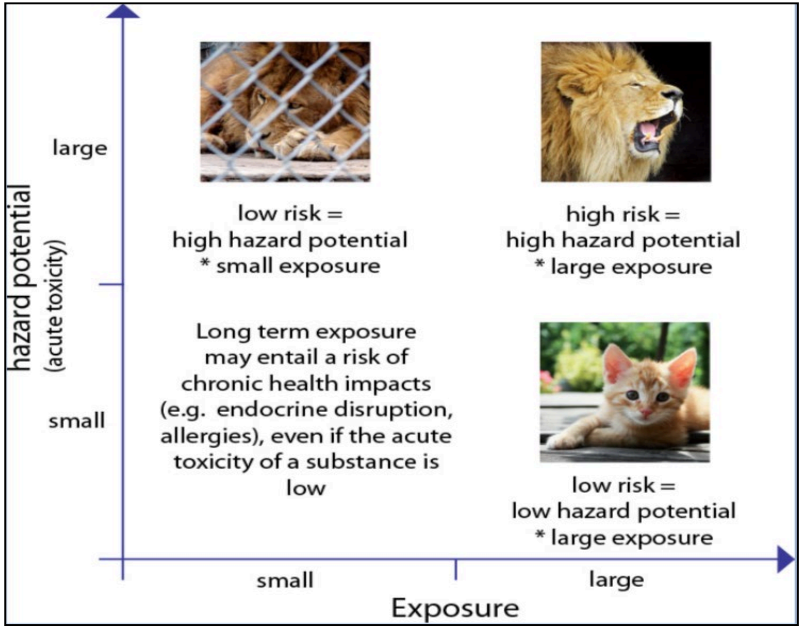
A **risk** is understood as the possibility of environmental or health damage. 'Possibility' refers to the uncertainty of occurrence, i.e. how big is the **exposure**? 'Possibility' also refers to the uncertainty about the **hazard**, i.e. how toxic or severe is the impact of a (microparticle) uptake. The risk possibility follows the equation:

Risk = Hazard x Exposure



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Risk Assessment Approach for Lay Persons

Exposure / Dosage	Toxicity / Hazard potential
The likelihood and extent to which organisms (incl. humans) come into contact with microplastics. Exposure describes the amount of microplastics, or chemicals thereof, to which an organism is subjected to over a certain time period.	The intrinsic ability of a substance to disrupt biological processes in living organisms. This factor describes the inherent property of a certain microplastic and depends on physical/chemical substance properties as well as the nature of the target organism.

Task: Please assess your personal risk (hazard/exposure) to microplastic impact using the scale of the figure by Köhler (2015).

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Hazard Assessment - Background Info

- The magnitude and duration of exposure determines the dosage that a target organism can absorb. A higher dose with short duration of exposure may cause acute toxic effects whereas long-term exposure at low doses may lead to chronic health effects or cumulative environmental impacts.
- The toxicity of most substances follows a non-linear dose-response relationship: at small doses, no adverse impacts can be observed (effects can even be wholesome as in the case of pharmaceuticals) until the exposure exceeds a certain substance-specific threshold above which adverse impacts occur.
- Among scientists, there is a growing awareness for certain toxicological mechanisms (such as endocrine disruptors) for which a minimum effect threshold cannot be identified with certainty. A hazard potential should not be neglected even at low dosage because adverse long-term impacts cannot be ruled out until counterevidence has been established.

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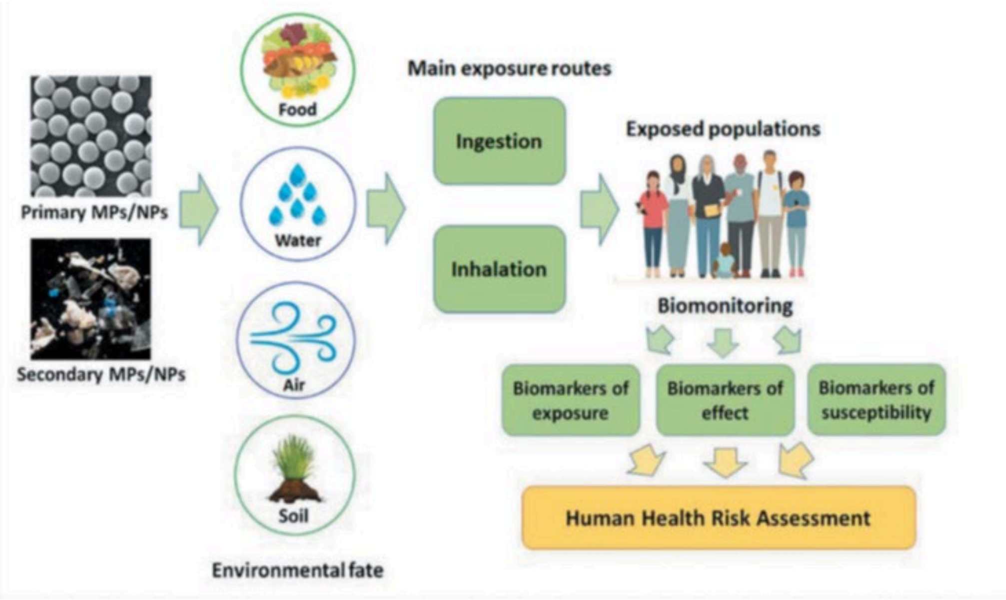
Human Health Risk Assessment via Biomonitoring Studies

There is no clear consensus in the scientific community as to whether risk assessments based on the available exposure and toxicity data are currently possible or not (Geueke, 2020).
For a final assessment of the microplastic-induced human health risks epidemiological studies are needed.



Rubio et al., 2020

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Microplastics:
Leaching of *Added* Chemicals and Monomers

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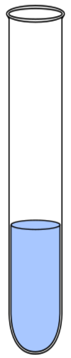
- *Unbound chemicals / non-polymeric chemicals*: Several thousand distinct additives are used for the production of synthetic fibres and plastics, including plasticizers, pigments, antimicrobial agents, heat stabilizers, UV stabilizers, fillers, and flame retardants.
- These additives account for approximately 4% of the weight of microplastics (Wright & Kelly, 2017; Prata et al., 2019).
- *Unreacted Monomers:* Other chemicals like antioxidants, UV stabilizers, nonylphenol and Bisphenol A. (Bisphenol A is an endocrine disruptor with hormone like estrogenic-activity. It also interferes with cellular gene-regulation.)



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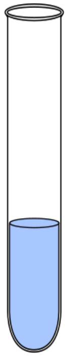
Microplastics: Transfer of *Absorbed* (Ambient) Contaminants

- Microplastics are considered to absorb and thus act as vectors for pollutants. Because of their high surface area to volume ratio and hydrophobic surface, microplastics can adsorb and concentrate hydrophobic organic contaminants to a high degree, such as
  - polycyclic aromatic hydrocarbons (PAHs)
  - organochlorine pesticides like dichloro-diphynyltrichloroethane (DDT)
  - hexachlorobenzene (HCB), polychlorinated biphenyls (PCBs).
- Microplastics also accumulate heavy metals (cadmium, zinc, nickel, and lead).
- Inside the body: Pollutants easily desorb under physiological conditions in the digestive and respiratory tract systems. Leached chemicals are likely to *bioaccumulate* (Jiang et al., 2020).



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Microplastics:
Inhalation of Indoor Air Microfibres

- Microfibre concentrations are higher in air indoors than outdoors up to 60 fibres/m^3 (Prata et al., 2019).
- Indoor microplastics: 2/3 of fibres are non-synthetic/cellulosic, and 1/3 is synthetic mainly PP from carpets or furnishing.
- Some observed fibres are too large to be inhaled but the exposure may occur through dust ingestion, which is particularly a risk for young children.
- Studies showed that abrasion of fibres and particles from flame retardant treated curtain upholstery led to spiked flame retardant concentration in ambient dust samples. (Abdallah & Harrad, 2018).

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Occupational Health Aspects

- *Respiratory irritations*: Studies among nylon flock workers found that 4% of the personnel had interstitial lung disease with coughing, breathlessness and wheezing (Lai & Christiani, 2013). Histopathological analysis of lung biopsies from workers in the textile (nylon, polyester, polyolefin, and acrylic) industry showed connective tissue disorders (interstitial fibrosis).
- *Byssinosis* is a non-specific chronic respiratory disease in textile workers exposed to dusts of cotton, hemp or flax (due to cellulosic microfibres).

Sarkar, 2013

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Occupational Health Aspects

- *Cancer suspicion*: Both cellulosic and plastic microfibers have been observed in non-neoplastic and malignant lung tissue taken from patients with different types of lung cancer, i.e. the fibres are biopersistent. Fibres of 15-20 µm length cannot be cleared efficiently from the lung and fibres with a length between 0.3-10.0 µm are carcinogenic (Singh & Chadha, 2016).
- Elevation in *risk of miscarriages* of dust exposed textile workers in Shanghai area (Wong et al., 2009).

Sarkar, 2013

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How to Reduce Microplastics by Shopping Behaviour

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- Buy clothing made from organic polymers or natural fibres such as cotton, linen, silk or wool. Maximise the use of textiles made from biodegradable and renewable fibres (taken the respective resources into account).
- Buy less or clothing from sustainable (slow fashion) brands (Šajn, 2019).
- Prefer second hand, swap or donate clothes (thus avoiding e.g. new packaging).
- Participate in clothes collections for re-use, repair and upcycling (instead of incineration or landfill).

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- Watch out for increased transparency and environmental labelling.
- Task: Discuss your options and reflect your purchasing behaviour.

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How to Reduce Microplastics in Use and Care

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- Wash less if you can (Gray, 2017).
- Utilise the full load of the machine.
- Use colder settings for synthetics (30-40 degrees).
- Use liquid detergents because they are less abrasive.
- Reduce spin speed because it provides less agitation.
- Use clothesline as tumble drying releases 3.5 x more fibres than washing (Kapp & Miller, 2020).

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Tasks:

... Reflect your own washing behaviour

... What can you improve?

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How Future Technologies May Reduce Microplastics Release from Apparel Washing

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- Changes in the fibre, yarn, fabric, and the clothing design construction (in terms of durability and biodegradability). Natural cellulosic and protein fibres are thought to be better for the environment and for human health. Man-made fibres such as Lyocell, made from cellulose in a closed loop production cycle, allow recycling of 99% of the chemicals (Lenzing AG, 2020).
- Modification in the washing technology, for example improved filtering systems.
- Improved filtration systems in wastewater treatment processes.

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