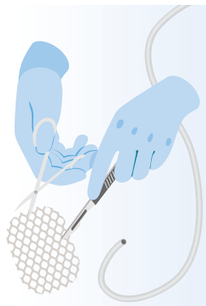
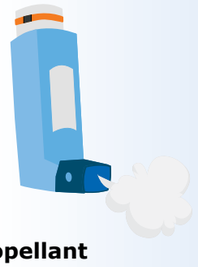
PFAS in the medical products chain

Product category	Production of the raw material	Manufacturing of the final product	Usage	End-of-life	After end-of-life / fate
 **Medical textiles**	PFAS chemicals are produced in large batches. Subsequently, purified PFAS (mixtures) are processed into coatings, membranes or fibers at a separate facility. For textile coatings, liquid **side-chain fluoropolymers (SCFP)** are often used. Production losses and byproducts may result in potentially toxic emissions to water and air; inadequate tank cleaning and waste incineration at too low temperatures also cause emissions. Fluorochemical companies	PFAS coating is applied, textile dried and heated. Textile finishing/padding: aqueous coating containing the side-chain fluoropolymers wets the textile. Excess fluid is pressed out and the textile dried. Side-chain fluoropolymers have a low melting & boiling point. Gaseous emission could occur, products disintegrate into toxic PFAS types. Textile manufacturers, wastewater treatment, people waterproofing textiles and shoes periodically.	Both reusable and disposable coated textiles can be used in e.g. operating rooms. Likely limited issues during wear. Laundering of reusable textiles may release certain fibers, potentially introducing PFAS into the sewer system. Medical professionals who wear the textiles and (dry) cleaners of used textiles.	The choice in end-of-life treatment depends on the individual judgement of hospital personnel and hospital policy. Side-chain fluoropolymers can biotransform into PFAS after landfilling. Solid waste incineration potentially emits PFAS to flue gas or ash, instead of destroying it. Hospital, waste collecting and sorting companies, final treatment centers, local authorities	PFAS released into the environment will be transported through air and water. Potential toxicological effects on various organisms. The higher in the food chain, the higher the risk usually is. Wastewater treatment plants can concentrate PFAS from waste- and surface water into sludge.
 **Implants & meshes** **Tubes & catheters**	**Fluoropolymers** are produced in complex processes with multiple steps in specialized plants. Small PFAS are used to enable the desired reactions and can be formed as undesired byproducts. Small PFAS can be toxic or harmful to the environment when emitted. Fluoropolymers are currently not considered as harmful themselves, neither are compounds thereof. Fluorochemical companies.	PTFE, FEP, and other fluoropolymers undergo processes such as extrusion, stretching, pressing, and more, to be transformed into products. Scrap is likely disposed of as residual waste and incinerated at low temp, leading to PFAS emissions in flue gas and ashes. Compounders, production companies specialized in medical items.	Implants and meshes are typically permanent fixtures that remain within the body, while tubes and catheters are utilized for shorter durations. No emissions expected during use or product lifetime. Patients, medical professionals.	Implants may be burned at crematoria or buried at cemeteries. If they contain PFAS, this will not be destroyed properly. Tubes and catheters may end up in specific and non-specific hospital waste, to be incinerated in different ways. Incineration at too low temperature causes PFAS emissions into gas and ashes. Waste collection and sorting centers, crematoria, waste incinerators, cemetery owners.	Emissions during incineration may be in gases, liquids or solids and spread further. Every incinerator is different in design and operation. Little is known about the products of complex reactions in these processes and monitoring is insufficient to have a complete overview if and where PFAS are emitted in this stage. Once emitted, gaseous PFAS are not removed from the environment.
 **Propellant**	Propellants (mainly HFA-227 and HFO-1234ze) are **PFAS gases**. Small emission volumes to be expected during production and transport due to gaseous state of the material, some with high global warming potential. Small number of fluorochemical companies	Few production steps required; mainly purification, testing and packaging. Typically done by manufacturer. Each handling step potentially causes small volumes of emissions. Indications of persistence, and little research on toxicity. Same fluorochemical companies that produce raw material for these products.	Used as aerosol to form small droplets of medicine for inhalation. Propellants are inhaled together with the drug, then exhaled and released into the environment. Patients, medical professionals.	Empty canisters can be collected. Propellants are not recovered. Non-emptied canisters will be emptied at some point during waste treatment. Unsorted waste will be incinerated or landfilled. Patients and medical personnel	HFO-1234ze partly transforms into trifluoroacetic acid (TFA) in the atmosphere. TFA toxicity is limited but persistence is high. There are potentially still unknown toxicological effects. Once dissolved in seawater, TFA is not removed by human technology.

How PFAS affect(s) the product category in each part of the product chain. How PFAS emissions can be formed and what they may look like. Main actors, excl. governmental bodies

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PFAS in medical applications: usage, emissions & health effects

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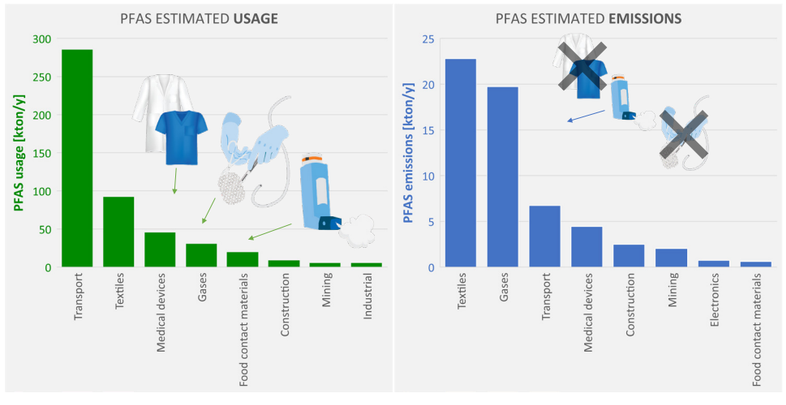
PFAS usage

In the graphs below, the estimated **annual usage and emissions** of PFAS in the EU are shown. Data are based on the EU PFAS restriction proposal.



** Please note that some items used in medical applications classified as textiles (e.g. surgical gowns, drapes) or gases (propellants for inhalers).

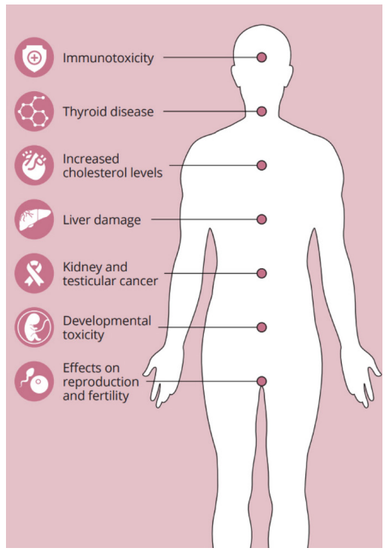
The medical sector is already associated with a **significant share** in the PFAS emissions. With an ageing population and increasing access to advanced healthcare in the EU, the **relative contribution of the medical sector will increase** if no action is taken. In a Belgian market study, the medical sector is even considered to be the largest contributor to PFAS emissions.

Currently, it is estimated that **propellants in inhalers** cause the highest emission volumes in the medical sector. This volume could be estimated rather well compared to the emission volumes of other products, as emissions occur during use. Emissions caused by PFAS used in medical devices and textiles mostly occur during end-of-life treatments, which are not shown in the graph above due to limited reliability of the data.

Effects on health

All PFAS molecules are **persistent:** they don't or barely degrade in the environment. Many are **mobile** and **bioaccumulative**, some are **toxic**. Not all PFAS have been proven to cause adverse health effects, in part related to the existence of thousands of different molecules that are a PFAS.

Even if a PFAS is not harmful, manufacturing and end-of-life processing of that material could lead to emissions of other PFAS with a worse toxicological profile.



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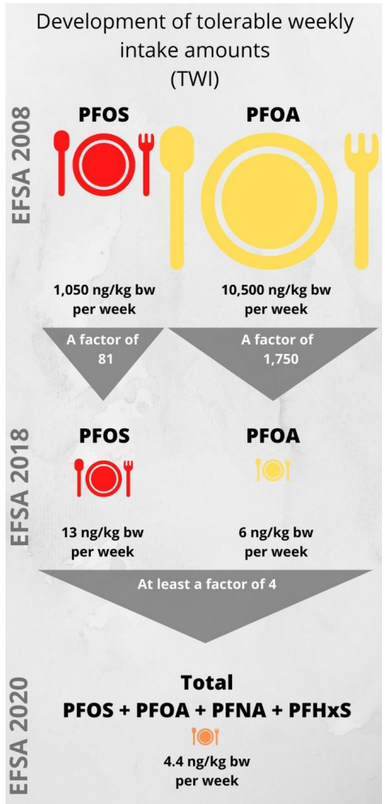
The **precautionary principle** is a rationale for a cautious approach when introducing new chemicals. The figure above indicates its relevance to PFAS.
In just a few years, the tolerable intake was reduced enormously.



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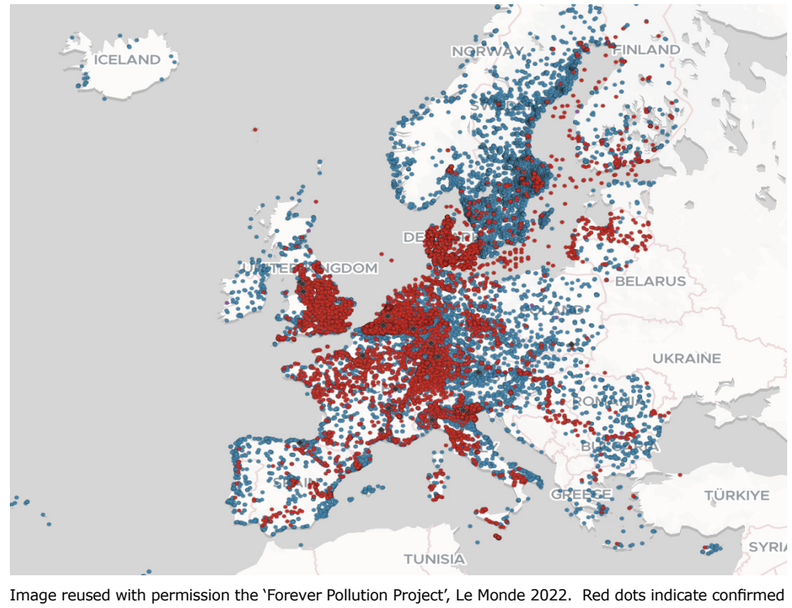

Image reused with permission the 'Forever Pollution Project', Le Monde 2022. Red dots indicate confirmed contamination, blue dots presumed contamination, and purple dots are known industrial PFAS users.

PFAS emissions

PFAS emissions mainly occur into water and air, this happens during different stages the product lifecycle. Some PFAS (mostly fluoropolymers such as PTFE) generally don't cause emissions when present in end products, their use is currently considered safe. Some treatments (heating, contact with chemicals) may however still cause emissions.

PFAS used as a manufacturing aid during fluoropolymer **production** cannot be recycled or recovered completely and may be emitted through flue gas or wastewater.

Incineration processes can degrade PFAS if the process is suitable. Most importantly, the temperature needs to be sufficiently high: almost all PFAS mineralize completely at >1200 °C. Municipal waste is usually incinerated at 850-950 °C, causing partial degradation and formation of potentially toxic, smaller PFAS molecules. Conditions in hazardous waste incinerators and cement kilns should suffice to complete mineralize PFAS.

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