MedTech Europe Position on the Proposal for A REACH Universal PFAS Restriction

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POSITION PAPER

MedTech Europe
from diagnosis to cure

Contents

Executive summary

MedTech Europe shares the ambition of the EU Chemicals Strategy for Sustainability[1] to boost innovation for chemicals that are both safe and sustainable by design. The sector is committed to the highest standards of chemicals risk management measures and is working with its suppliers to continuously improve the performance of its products and processes. At the same time, the medtech sector is ensuring the timely availability of lifesaving and life-sustaining technologies to satisfy patients' health needs. Medical technologies are regulated under stringent sectoral legislation, i.e., Regulation (EU) 2017/745 on Medical Devices (MDs) and Regulation (EU) 2017/746 on In-Vitro Diagnostics (IVDs) [2], which has been adopted after enacting the EU REACH Regulation 1907/2006. These sector specific regulations lay down requirements for the design, safety, quality, performance, alternatives assessment and validation of MDs and IVDs, which are processes that require a significant amount of time and R&D, in addition to the continuous search for alternatives for chemicals proposed for phase-out at EU level. The proposed EU REACH Restriction of per- and polyfluoralkyl substances (PFAS) is one such example. In addition, the PFAS Restriction proposal is of unprecedented scale not only in terms of number of substances in scope, but also their varied physical, chemical and hazardous properties, and the amount of essential medical technologies impacted.

PFAS uses in the medical technology sector or its supply chain occur due to their combination of different and essential properties including chemical resistance, heat resistance, durability, lubricity, low dielectric constant and/or biocompatibility. PFAS substances play a key role in achieving the required high performance and durability of the technologies critical to precision and reliability of medical applications, especially in the light of the above mentioned sectoral legislation.

Given the need for such a combination of essential properties, there is often no alternative available to the use of PFAS in many medical technologies, their (sterile) packaging or upstream manufacturing processes. Often, the only proposed alternative is another type of PFAS. In addition, any alternative must also fulfil all other regulatory requirements for use in medical technologies, including, required validations, aging tests, change of tooling and production processes, biocompatibility tests, clinical trials for certain devices, regulatory approvals and registrations, according to sector specific legislation (i.e., MDR and IVDR). Without successful completion of such required regulatory assessments and the necessary time to carry them out, a potential alternative material is neither able nor allowed to replace a given PFAS for use in MDs or IVDs.

Consequently, MedTech Europe's primary preoccupation with the unique PFAS Restriction proposal in terms of its enormeously vast scope combined with tight timelines is geared towards **preventing any supply shortages of medical technologies to the detriment of millions of patients** when considering a gradual transition to PFAS-free alternatives wherever technically feasible, MDR/IVDR proof and capable of ensuring the intended purpose of the medical technology to the continued benefit of patients.

[1] European Commission, Chemicals Strategy website, available at: https://environment.ec.europa.eu/strategy/chemicals-strategy/implementation_en
[2] Regulation (EU) 2017/745 of the European Parliament and of the Council of 5 April 2017 on medical devices and Regulation (EU) 2017/746 of the European Parliament and of the Council of 5 April 2017 on *in vitro* diagnostic medical devices

The current PFAS Restriction proposal would result in **significant impacts on the quality and availability of treatments for patients in the EU**. Due to the unavailability of suitable alternatives to PFAS some products would have to be removed from the market. Certain diseases and conditions could no longer be treated at all or no longer be adequately treated, such as for example, by devices required for minimally invasive interventions. If these devices disappeared, the alternative options would be open, maximally invasive surgeries, which vulnerable patients often cannot undergo or do not survive. For certain patients, there are no alternatives to interventional procedures with subsequent impact on their lives.

Companies have been working with their suppliers to map PFAS uses in medical technologies and continue to find further use cases as time goes on. Due to the sheer number of substances in scope of the Restriction proposal and highly complex multitiered healthcare supply chains sometimes involving thousands of suppliers, there is the high risk that uses of PFAS that have not been identified by the end of the ECHA consultation period would fall outside the scope of derogations and would therefore not be permitted for use.

Finally, **the medical technology sector is constantly looking for ways to innovate state-of-the-art technologies**. PFAS offer many benefits in medical technologies, due to the unique combination of properties they offer in a single material. The Restriction of this entire class of substances risks halting future medical technology innovation. Industry needs clarity and legal certainty regarding research priorities for alternative substances, since the discovery of viable alternatives to the thousands of different PFAS substances, cannot be accomplished and incorporated into medical technologies at the same time.

For the way forward with the PFAS Restriction proposal, MedTech Europe recommends:

1. **An overall patient-centric approach** whereby patient safety needs are considered when transitioning away from PFAS (where technically and economically feasible).
2. **A realistic transition pathway to non-PFAS alternatives** that are reliable and feasible for medical technologies (including their manufacturing and supply chain) to avoid shortages of medical technologies for patients and practitioners. Sufficiently broad derogations should allow sufficient time to first identify all PFAS uses in medical technologies, and to subsequently move to alternatives where these are proven to be technically viable, available and in conformity with the sector specific MD and IVD Regulations as well as fit for the intended purposes of the medical technology. A realistic timeline must consider the sector's complex supply chain dependencies as well as the long development timelines and steps to ensure compliance with the sectorial legislation (please see MedTech Europe response to ECHA consultation[3]).
3. **A differentiated approach to high risk and low risk PFAS** in line with Article 68.1 REACH, which requires a proof of "unacceptable risk" for enacting a REACH Restriction: high risk PFAS should be targeted first. Fluoropolymers have a proven history of use and safety in medical technology applications and differ distinctly from the broader PFAS group. They should therefore be subject to a more flexible approach including an at least 13.5 year derogation and transitional period in medical technology applications and a review possibility for its prolongation where duly justified.

[3] MedTech Europe's response to ECHA public consultation, Part 33 is available here: https://echa.europa.eu/documents/10162/28562aa5-2396-c7fa-efc3-f9ba60a30ff9

4. **A safeguard mechanism** for cases where no alternatives will be available, and for newly identified non-derogated cases or potentially missed use cases to ensure quality and continued access to essential medical technologies containing PFAS or requiring PFAS for their manufacturing, as well as their upstream supply chain.
5. **An inclusion of upstream suppliers and manufacturing in medtech derogations:** Where medical devices and IVDs are granted the necessary derogations, these need to include the materials and components supplied to the medtech sector as well as manufacturing processes and process aids to be workable.
6. **An enabling R&D framework** that supports medical technology manufacturers in the unprecedented challenge of finding numerous use-specific, fit-for-purpose alternatives to PFAS medtech applications that are also satisfying MDR/IVDR regulatory requirements without compromising patients' lives or health.

In this paper, we substantiate our requests by providing further background information regarding:

- PFAS use cases in the medical technology sector (Chapter 2, Annex 2 and Annex 3),
- The sector's specificities in terms of supply chain complexities and sector specific, regulatory environmental,human health and safety considerations (Chapter 3),
- MedTech Europe's suggested key building blocks for a workable transition pathway (Chapter 4), as well as
- Underlying case studies (Annex 1),
- An overview of the redesign steps in practice (Annex 4) and
- A scientific PFAS and Fluoropolymers Emissions Bibliography (Annex 5).

Chapter 1: Uses of PFAS in the medical technology sector

PFAS are used in medical technologiesdue to their combination of specific properties, including, but not limited to, chemical resistance, heat resistance, durability, lubricity, and biocompatibility. PFAS uses in medical technologies can occur:

- either in a component or coating of a component of the final medical device (MD) or in vitro diagnostic device (IVD);
- or as a processing aid used during device or upstream manufacturing and testing;
- or in the device part of an integral drug device combination;
- or as cell replacement therapies;
- or in their packaging.

PFAS substances play a key role in achieving the required high performance and durability of the technologies, which are critical, e.g., for precision and reliability of medical applications, especially in the light of the applicable sectoral legislations, i.e., Regulation (EU) 2017/745 on Medical Devices (MDs) and

Regulation (EU) 2017/746 on In-Vitro Diagnostics (IVDs). These regulations lay down strict requirements for the design, safety, quality, performance, alternatives assessment and validation of MDs and IVDs to ensure the protection of patients' lives.

A non-exhaustive list of the various uses of PFAS in medical devices and IVDs can be found in Annex 1, and a non-exhaustive list of the different types of PFAS used in medical technologies can be found in Annex 2 of this paper.

Chapter 2: Challenges in finding alternatives in the medical technology sector

Given the need for such a combination of essential properties, there are either no alternatives, or only "proposed options of alternatives" available to the use of PFAS in many medical technologies, their (sterile) packaging, washing, upstream or manufacturing processes, which could potentially deliver similar functionalities. The challenge is that the technical properties based on inertness (such as oil, water, thermal, biological, chemical and fire resistance) are the very reason why PFAS are also of concern in the environment (mainly its persistence). Because of the unique properties of PFAS, often the only proposed alternative to a given PFAS use is another type of PFAS.

To identify an alternative for a PFAS use, first, a proposed alternative is assessed by material scientists for its possibility. If a possible alternative is identified, the whole development cycle has to be followed from analysis and (in silico) evaluation, early feasibility assessment and test, to physical verification and validation including aging testing, biocompatibility tests including extractable and leachable tests, pre-clinical and/or clinical evaluation as required by the stringent sector-specific legislation. When that has been successful the regulatory steps have to be taken before the product can be placed on the market. Until the very last step in the development cycle of/for a potential alternative, it is possible that the use may be not deemed acceptable in the medical technology and a new alternative would have to be considered. For more details of the steps of the design cycle, please see Annex 4 – "Overview of the design cycle steps required for a medical technology".

Product, material and chemical innovation is a constant and integrated process. New products often include clinical improvements, improved treatment methods, and sustainable innovations (e.g., substitution of the most hazardous chemicals where feasible). The product life cycle of medical technology, due to its development time and required regulatory obligations, varies between years to decades, while the chemical and sustainability agenda in the European Union installs changes at an ever faster pace. This misalignment can be improved by properly taking into account the differences between new medical products and existing products already placed on the market, when setting sustainability requirements (including chemical restrictions). This will integrate the medical and sustainable innovation and ultimately bring new healthcare products more efficiently to patients.

As regards indirect uses (i.e., a PFAS used by a supplier to manufacture a supplied part) the described process can only start once a supplier declares the presence of a PFAS in a part to the medical device manufacturer.

An insufficiently broad framing of derogations or insufficient time to find suitable alternatives to current PFAS uses in medical technologies are likely to have consequences for patients, such as:

- **Potential patient death**. Percutaneous interventional procedures rely on the guidewire device to the target lesion. Without guidewire, there will be no life saving procedures. For example, stenting is needed for a severe heart attack patient, or dialysis for chronically ill patients to save his/her life.
- **Longer procedure times or increased stress to the patient**, e.g., PFAS coatings of catheters and PTFE contained tubes allow for their smooth insertion into the vasculature. Without the PTFE coating or PTFE tubing, clinicians may confuse the wire sticking to the vessel for a larger, more critical vessel blockage and not be able to differentiate in the severity of the issue. Guidewires that "stick" to the vasculature can cause thrombosis and patient harm.
- **Negative impacts on the quality of treatments:** Medical device procedures (such as endoscopic procedure) being replaced with much **more invasive and higher-risk procedures** (such as open-heart surgery), which would significantly increase patient trauma and may be detrimental to vulnerable patients, such as elderly, multi-disease patients. Invasive procedures often lead to increased or repeated hospital stays, longer recovery times, increased cost for the patient, and delayed re-entry into the workforce if applicable. Subsets of patients with pre-existing conditions and/or comorbidities may not even be eligible for open surgery.
- A **discontinuation of life-saving technologies and services** (e.g., procedures for stenting, heart valve repairing and replacement, catheters, implants, life-saving replacement therapy in case of organ failure, and capital equipment used in related procedures, leading to patients being untreated or suboptimally treated) and IVD uses (e.g., instruments, diagnostic testing kits), leading to undiagnosed conditions, whereby e.g., the lives of patients suffering from organ failure will be at risk.
- An **increased incidence** of puncture wounds, thrombosis, inability to deliver the device to the targeted lesion, device malfunction and/or the inability of the surgeon to sufficiently visualize the surgical site.
- **Complications during treatment and other negative impacts on the patient's wellbeing,** e.g., no or improper interventail procedure at cardiac emergency, vein complications and tissue damage during interventional access, and improper healing in the case of hernia meshes. This may cause patient death or delay the patient's treatment and adversely affect post-treatment life. Additionally, the increased treatment times and complications will not only adversely impact the patient's overall health, but also the economic state of the patients and their families and the health system.
- An **inability to manufacture or source critical components** for medical technologies, e.g., humanitarian medical devices. It may cause suppliers to terminate their production and hence disrupt the distribution of medical technologies within the EU. Additionally, a shortage of possible alternative materials (e.g., the same category of the materials, but from a different supplier) may arise due to a sudden high demand from several manufacturers.

Chapter 3: Specificities of the medical technology sector

Medical technologies are strictly regulated under sectorial legislation for performance, safety, and risk management. Therefore, medical technologies containing PFAS are considered safe for the patient and user,

due to the rigorous validation processes and biocompatibility tests they are obliged to undergo. In addition, certain requirements exist for the justification and labelling of chemicals used in medical technologies. Where changes in the chemical or material composition occur, long and comprehensive validation processes are triggered (see Annex 4 – "Overview of the design cycle steps required for a medical technology").

It should also be noted that the multiple regulatory initiatives running in parallel to PFAS in the chemical's domain (e.g., BPA + BoSC, DEHP, microplastics, lead, etc.) also lead to alternative substitution requirements and collectively are creating a heavy burden on industry R&D ressources. When many material and design change dossiers are submitted to regulatory bodies around the world simultaneously, they will be overwhelmed by the volumes resulting in probable delays in marketing the product in the EU. Resources may be better allocated towards new medical technology innovation, rather than phasing out chemical uses from approved safe technologies that are essential for many patients. Human ressources that would otherwise be dedicated to treating new disease states, seeking solutions for new patient populations, and solving unmet clinical needs would likely be displaced to research in PFAS-free alternatives for existing products. European society, especially patients, will suffer due to dependence onold medical technologies or missing and reduced treatment options.

Supply chain complexities

The medical technology sector represents over 500,000 products, services and solutions available on the Union market. Individual devices differ greatly in terms of complexity. It is not uncommon for routinely used devices to have hundreds and thousands of components. Supply chains can be up to 30 tiers from materials to the final device. A single component of such products being banned due to a missed identification of its PFAS relevance or due to a too narrow or too short derogation (exact wording) can make the concerned devices and medical treatments unavailable for patients.

Given to the broad relevance of PFAS in industry and the unprecedented scope of the proposed Restriction, the current disclosure requirements, such as via safety data sheets, SVHC declarations or other means are insufficient to build the basis for identification and evaluation of all relevant PFAS uses in time within the expected legislative timeline.

In the absence of a workable regulatory obligation to disclose whether the provided products, components and materials contain PFAS or use PFAS for their manufacturing, there is a high likelihood that the medical technology sector is not yet aware of all uses of PFAS in components they use, or in the manufacturing of these components. Right now, there are also no single standardised analytical methods for all PFAS available. Against this background, it is questionable whether the proposed Restriction could be adequately enforced in connection with the import of PFAS containing products from third countries.

A Restriction of PFAS containing substances within the EU may cause suppliers to terminate their production and hence disrupt the distribution of medical technologies within the EU. Additionally, a shortage of possible alternative materials may arise due to a sudden high demand from several manufacturers.

In the end, all these aspects affect patients and customers, because the provision with the respective devices could not be ensured.

A strict sectorial regulatory system: human health, environmental protection and safety aspects

Human Health protection

Risk management is conducted in line with medical technology regulations (e.g., EU MDR and IVDR) and (harmonized) standards, as well as local governance biocompatibility studies and toxicology studies.

The existing regulations (e.g., EU MDR 2017/745 Chapter VI; EU MDR 2017/746 Chapter VI) require that manufacturers shall specify and justify the level of clinical evidence necessary to demonstrate conformity with the relevant general safety and performance requirements, as well as provide requirements for conducting of clinical investigations. Existing international standards (e.g., EN ISO 14155) address good clinical practice for the design, conduct, recording and reporting of clinical investigations carried out in human subjects to assess the clinical performance or effectiveness and safety of medical technologies.

In addition, manufacturers have established risk management systems (in accordance with EN ISO 14971). As part of the risk management, all known and foreseeable risks, and any undesirable side-effects, are minimised and need to be acceptable when weighed against the evaluated benefits to the patient and/or user arising from the achieved performance of the device during normal conditions of use. Furthermore, in order to ensure patient safety, the use of device materials must undergo rigorous biocompatibility testing in accordance with the ISO 10993 series on “Biological evaluation of Medical Devices, as part of standard medical device risk management requirements”, as part of the standard risk management process.

To illustrate, fluoropolymers and perfluoropolyether biomaterials are commonly used in medical technologies and other biomedical industries. The usage of these materials has been well-proven to be biocompatible and safe for patient use (over 45 years on the market) and well-regulated (EU MDR approvals and other regions' regulatory approvals).

Environmental protection and safety

Main PFAS emissions within the control of the sector are primarily emissions during manufacturing and end of life management.

As regards emissions during manufacturing, EU Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control)[4], which has just been revised, applies on manufacturing sites of the sector in the EU. Besides, many companies’ manufacturing processes are for example governed by the ISO 14001 standard, an established and internationally recognized management process for minimizing environmental impact in manufacturing. PFAS is an exceptionally broad term used to describe thousands of distinct chemicals with a diverse array of properties and uses in society. There are clear and important distinctions between the chemical, physical, and toxicological properties of various types of PFAS materials, which need to be acknowledged in the proposed Restriction. Certain PFAS have a high molecular weight, which generally makes them too large to be bioavailable and they are not mobile in the environment, posing a low environmental risk. Measuring environmental emissions should be based on the type of PFAS generated/manufactured in certain facilities.

[4] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control), available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32010L0075

As regards end of life management, the sectorial legislations (e.g., EU MDR 2017/745, Annex I, Section 14.7; EU IVDR 2017/746, Annex I, Section 13.6) rule that devices shall be designed and manufactured in such a way as to facilitate their safe disposal and the safe disposal of related waste substances by the user, patient or other person. Instructions for safe disposal are provided in the individual medical technology's Instruction for Use (IFU) (e.g., EU MDR 2017/745, Annex I, 23.4 (v)).

If the device does not have specific disposal requirements due to the manufacturer's risk assessment or another applicable material regulation (i.e., electronics disposal under the Directive 2012/19/EU on waste electrical and electronic equipment (WEEE), the IFU commonly instructs to dispose of the product in accordance with the locally applicable legislation and the healthcare facilities' biohazard waste procedures.

The medical technology sector uses mainly PFAS-containing materials that are applied in articles used in the healthcare environment and laboratory settings (e.g., hospital biohazard disposal is typically treated via incineration).

Degradation emissions of PFAS to air from the incineration of fluorinated polymers is highly dependent on the waste treatment conditions[5]. Control of amounts of such emissions, if any, would be also subject to the European Industrial Emissions Directive 2010/75/EC.

Besides, the medical technology sector has been very active in exploring novel methodologies in a highly regulated environment. R&D talent is exploring **chemical recycling, modular medical technologies, recycled sterilizable packaging, and even re-use of certain medical devices.** These resources are also evaluating **more sustainable manufacturing practices** (such as electronification), carbon footprint reduction, invention/investigation of new biomaterials, and many more.

Different levels of risks: The case of fluoropolymers

The majority of medical technology manufacturers are not producers of the underlying chemicals or resins that form the fluoropolymers in their finished devices. These device manufacturers receive materials as polymeric products or intervening component parts in chemically stable forms, which are then used to manufacture or assemble medical technologies. Therefore, the use case of these fluoropolymers is either for a manufacturing aid or the material remains in the final medical technology product, where the material may or may not be patient contacting. Furthermore, uses may be in the up-stream manufacturing of those components or manufacturing aids. The use is subject to strict control measures and external certification under the MRD and IVDR.

The fluoropolymers used in medical applications meet the criteria set out by the OECD for polymers of low concern[6]. They do not present toxicity concerns and are not degrading into perfluoroalkyl acids (PFFAs). They are not bioavailable, not bioaccumulative, are not mobile in the environment and pose no potential for long-range transport (LRT). Thus, fluoropolymers do not impact drinking water, plants, or crops.
Fluoropolymers have unique physicochemical properties that constitute a low concern distinction within the PFAS group as they are "chemically stable, biologically stable/inert, negligibly soluble in water, non-

[5] Wahlström, et al., 2021. Eionet Report – ETC/WMGE 2021/9, Emissions of PFAS to air from the incineration of fluorinated polymers, page 60
[6] OECD, Data Analysis Of the Identification of Correlations Between Polymer Characteristics and Potential for Health or Ecotoxicological Concern, page 10, January 2009, available at: https://www.oecd.org/env/ehs/risk-assessment/42081261.pdf

bioavailable, non-bioaccumulative; and non-toxic"[7]. Emissions during the manufacturing processes of medical technologies are controlled and meeting local regulatory requirements.

Per Table 1 of the PFAS Restriction proposal, annual polymeric PFAS used in the medical device industry make up only 2.75% of the total (mid) estimated amount used across the major use sectors. The emissions percentage is even lower for medical devices, at 0.38% of all polymeric PFAS emitted to the environment across all major use sectors.

Furthermore, because of their long history in the highly regulated healthcare field, fluoropolymers have an extensive biological safety testing history and long track record of clinical safety. This stands in contrast to certain classes of low molecular weight PFAS that have been the key focus for public health concern. Fluoropolymers (and their applications in implantable and invasive medical devices) have been extensively studied, especially regarding biological safety.

If the PFAS Restriction proposal were enacted as suggested, R&D resources in corporates are likely to be focused on seeking a fluoropolymer alternative and withdrawn from other R&I areas. In addition, enacting the Restriction as proposed would contradict the goals of a circular economy, as products in use would have to be scrapped earlier than necessary due to a lack of spare parts and the implicit ban of refurbishment and repair.

There should be a differentiated approach to high risk and low risk PFAS in line with Article 68.1 REACH, which requires a proof of "unacceptable risk" for enacting a REACH Restriction: high risk PFAS should be targeted first. A more flexible approach including an at least a 13.5-year derogation period in medical technology applications and a review possibility for its prolongation should be applied to fluoropolymers. Their history of use and safety in medical technology applications are proven and they differ distinctly from the broader PFAS group.

Chapter 4: A workable PFAS transition pathway for the medtech sector

The timeline required for a transition to PFAS-free materials for medical technology depends on various factors:

- A multi-tier supply chain and the medical technology sector's main role as a downstream user of chemicals and components. As for most PFAS, there currently is no workable regulatory obligation for relevant information disclosure in the supply chain. The medical technology sector is likely not yet aware of all PFAS uses in components they use or in the manufacturing of those components;
- A proposed alternative is not the same as a validated alternative;
- Medical technologies are regulated under stringent sectoral legislation, which lays down requirements for their design, safety, quality, performance, alternatives assessment and validation. These are processes that require a significant amount of time and R&D, in addition to the continuous search for alternatives for chemicals proposed for phase-out at EU level;

[7] Henry, et al., 2018. *A Critical Review of the Application of Polymer of Low Concern and Regulatory Criteria to Fluoropolymers*. Integrated Environmental Assessment and Management 14(3): 316-334. http://dx.doi.org/10.1002/ieam.4035
See also Plastics Europe, Association of Plastics Manufacturers, *Fluoropolymers Product Group, Fluoropolymers vs. Side-Chain Fluorinated Polymers*

- Additional factors are the high complexity of products containing PFAS components, and the high number of products that a company will have to substitute concurrently.

To ensure the availability of vital medical technologies, MedTech Europe recommends:

1. **An overall patient-centric approach** whereby patient safety needs are considered when transitioning away from PFAS (where technically and economically feasible).
2. **A transition pathway to non-PFAS alternatives for medical technologies** (including their manufacturing and supply chain) based on realistic timetables that allow sufficient time to first identify all PFAS uses in medical technologies, and to subsequently move to alternatives where these are proven to be technically viable, available and in conformity with the sector specific MD and IVD Regulations.
   A realistic transitional timetable to non-PFAS alternatives needs to be reliable and feasible to avoid a shortage of technologies for patients and practitioners. A realistic timeline must consider the sector's complex supply chain and dependency on the supply chain, as well as the long development timelines and steps to ensure compliance with the sectorial legislation. Due to the large amount of medical technologies and their variety in terms of complexity, chemical design, and material design, there is no one-size-fits-all solution to the length of transitional time for all PFAS. The derogation periods vary due to the high level of uncertainty, such as:
   - Whether proposed alternatives meet the required functional properties;
   - The variety of products, its risk profile and the function of the PFAS containing material in the medical technology;
   - The different level of risks of PFAS used in the medtech sector, such as high risk PFAS and fluoropolymers;
   - The uncertainty of the future regulatory outlook and the application of the essential use concept, when the PFAS Restriction will enter into force or when the proposed derogations expire.
3. **A sufficiently broad approach to the derogations for IVDs and MDs to prevent imminent supply shortages:** As we work on the proposed PFAS Restriction, we are continuously identifying new PFAS uses. A detailed list of derogations at this stage can only be non-exhaustive and therefore runs the risk that applications will be missed. There is the risk that many of the PFAS uses in the sector are not known yet and will therefore not be taken into account at this stage.
4. **A safeguard mechanism for cases where no alternatives are available, and for newly identified non-derogated cases** to ensure quality and continued access to medical technologies containing PFAS or requiring PFAS for their manufacturing, as well as their upstream supply chain: For some of the medical technology uses of PFAS, the 13.5-year transitional period is not sufficient to find and validate a potential alternative, also considering the material and product design cycle and time for change implementation (please refer to Annex III – "Non-exhaustive list of types of PFAS used in medical technologies"). A 13.5-year transitional period creates the misleading assumption that an alternative will be available once this time has elapsed. This can however not be taken for granted considering the reasons mentioned above. As the technical conditions, regulatory requirements etc. differ significantly, the feasibility of PFAS substitution in one case does not mean that substitution is possible in other cases. In some cases, even if there is an alternative, it may have inferior benefit/risk assessment and/or performance. Besides, a similar mechanism for newly identified non-derogated cases is necessary to

ensure continued access to essential medical technologies containing PFAS to patients and practitioners (e.g., see complex supply chain section).

5. **A differentiated approach to high risk and low risk PFAS** in line with Article 68.1 REACH, which requires a proof of "unacceptable risk" for enacting a REACH Restriction: high risk PFAS should be targeted first. Fluoropolymers have a proven history of use and safety in medical technology applications and differ distinctly from the broader PFAS group. They should therefore be subject to a more flexible approach including an at least 13.5-year derogation period in medical technology applications and review possibility for its prolongation in the absence of a suitable alternative.
6. **A realistic transitional timetable to non-PFAS alternatives that are reliable and feasible** to avoid a shortage of technologies for patients and practitioners. Due to the large amount of medical technologies and their variety in terms of complexity, chemical and material design, there is no one-size-fits-all solution to the length of transitional time. A realistic timeline must consider the sector's complex supply chain and dependency on the supply chain, as well as the long development and regulatory approval timelines and steps to ensure compliance with the sectorial legislation.
7. **Derogation extension for upstream suppliers and manufacturing**: Where IVDs and medical devices obtain the necessary derogations, we rely on our suppliers to also have derogations for the materials and components they supply us with, but also for the manufacturing processes and aids. Otherwise the derogations for our "end uses" would become mostly obsolete, discriminating EU-based manufacturers. Furthermore, where an alternative material/component to PFAS should be made available, that material/component would then need to undergo validation processes under sectoral legislation to ensure patient safety and quality and performance of the finished product. If a time limited derogation is granted for the PFAS use in the supply chain of the medtech sector, the newly supplied material would nonetheless still need to be tested, validated and approved for use in the respective medical technology, and therefore sufficient time would be needed.
8. **An enabling R&D framework** that supports medical technology manufacturers in the unprecedented challenge of finding numerous use-specific, fit-for-purpose alternatives to PFAS medtech applications that are also satisfying MDR/IVDR regulatory requirements and not compromising patients' lives or health. Research priorities with respect to phase-out substances should be clear.

Chapter 5: About MedTech Europe

MedTech Europe is the European trade association for the medical technology industry including diagnostics, medical devices and digital health. Our members are national, European and multinational companies as well as a network of national medical technology associations who research, develop, manufacture, distribute and supply health-related technologies, services and solutions.

For more information, please see: www.medtecheurope.org.

Annex 1: Case studies[8]

MedTech Europe list a few examples of case studies illustrating the challenges for medical technologies with the PFAS Restriction proposal in its present form:

1. Implantable and invasive medical devices

Among the implantable and invasive medical devices, there are interventional cardiac occluders and endoprostheses, surgical vascular grafts, cardiovascular patches, surgical sutures, implantable ophthalmic applications, hernia mesh, endoscopes or cleaning solvents, to name a few. Fluoropolymer-containing or coated medical devices have been implanted in patients for 45+ years safely and effectively. Fluoropolymers are biocompatible, bioinert, are stable when implanted, durable, non-toxic, chemically and heat resistant, provide a low coefficient of friction, allow tissue growth, and are strong and flexible. Currently, there are no alternatives that meet all these properties and/or have the successful clinical history of fluoropolymers. Replacement of materials used in implantable [and invasive] medical devices (and their manufacturing processes) is a drastically more complex and resource-intensive undertaking than in most other applications and industries. It is estimated that development, validation, clinical studies, and regulatory approval of a material substitution in implantable medical devices would take ~20 years for a single device. For patient contacting and implantable devices, special requirements for carcinogenic, mutagenic and reprotoxic (CMR) and endocrine disrupting (ED) substances apply. The usage of CMR and/or ED substances requires justification, which includes a risk-benefit analysis. Currently, over 1,200 CMR/ED substances need to be addressed under Section 10.4 of MDR. Fluorinated polymer processing aids (PPA's) as well as the upstream supply chain need to be derogated to allow the manufacturer to continue medical device fluoropolymer manufacturing.

2. Complex equipment – e.g., equipment for organ replacement (active medical devices), packaging and spare parts

One example of concerned complex equipment are devices, which are used to replace essential body functions in case of acute or chronic organ failure, keeping hundreds of thousands of patients alive worldwide. Spot-checks by a single manufacturer already identified more than a hundred different components, consisting of several different fluoropolymers. Uses include e.g., parts of valves that must be biocompatible. Further parts, which are common industry standard like O-rings, batteries or electronic components, certainly exist and will further increase the number of concerned parts. Besides, the above-described active medical devices, PFAS are also relevant for manufacturing and packaging of needed single-use disposables. Qualification of potential alternatives must be done for each concerned component individually, considering the specific technical and regulatory conditions. In the majority of components, a material change would also impact the tools used in production. This significantly increases the time and efforts required. Besides design of current and future devices, also the already phased-out products must be considered. Concerned devices are investment goods, are intended to be used in clinics and hospitals for several years. Thus, the availability of spare parts for maintenance and repair of devices must be ensured for the whole use phase, i.e., approx.. 10 years after stop of production. Each change of the product design and related tools must follow strict rules

[8] For more case studies, please refer to MedTech Europe's response to ECHA public consultation, Part 33, available at: https://echa.europa.eu/documents/10162/28562aa5-2396-c7fa-efc3-f9ba60a30ff9

and processes to comply with applicable quality, safety and regulatory requirements. Experiences with past substance replacements (which were less complex and affected less numerous changes of materials) already indicate that a substitution of PFAS, if feasible at all, would take a significant number of years. Needed internal and external resources for technical qualification, bio-compatibility assessments and regulatory affairs for the required number of parallel substitution projects within such short timeframe are currently not available. Furthermore, such analysis of potential alternative materials, design changes, change of tools etc. could only start after identification of a component containing PFAS. The active medical devices consist of thousands of components and materials, partially designed and manufactured in-house, partially, especially in case of electrical components, manufactured and supplied in a multi-tier supply chain. Due to the broad scope and low threshold values of the proposed PFAS Restriction, existing PFAS disclosure and resulting data is incomplete and mostly limited to obvious cases, e.g., if fluoropolymers are the specified material of a supplied mono-material component. Experience with RoHS showed that generation of reliable and complete material compliance data takes years. In case of spare parts for products, availability of needed detailed PFAS data and willingness to invest in evaluation and re-design of components by concerned suppliers is highly questionable.

3. IVD reageants

PFAS substances are used in IVD devices such as IVD testing kits for hemostasis products (at an extremely low concentration and volume) which detect blood coagulation. They are used as well as heat-transfer agent in IVD clinical chemistry diagnostic testing instruments, which is essential to the functioning of the instrument. The PFAS substance is needed to maintain the temperature of the reaction cuvette. It ensures that the reaction which detects the disease or condition occurs under the correct conditions for a correct patient result. Manufacturers of IVD reagents and systems fluids are required under specific regulations to adhere to design change procedures that can take between 3 to 12 years to complete in order to meet the requirements for reasons of safety and performance. They are also subject to regulatory approvals in every country where sold (can be up to 42 months). This is for one substance only. When considering that a group of PFAS could be banned which may include up to thousands of PFAS substances, the redesign may take more than 12 years when for multiple products. The minimum approval time in case of materials with contact to blood or similar criticality is approximatively 3 years and can further exceed this range, e.g., if local registration updates require additional clinical studies. In case of materials with contact to high aggressive (THF, Chloroform and Acetonitrile) or similar criticality, the minimum approval time is approximatively 3 years and can further exceed this range. Additional use of PFAS in IVDs include that of trifluoroacetic acid (TFA) as identified in section A.3.10.1.14. of Annex XV of the proposed Restriction as an additive to the mobile phase in high-performance liquid chromatography applications and as an ingredient. Additionally, polymeric PFAS materials are widely used in IVD manufacturing process, including tubing, O-rings, Teflon stir bars, greases, water treatment, etc., i.e., essential uses of PFAS not ending up in the finished IVD. Unfortunately, no derogation has been given for these use cases. The reason for using these PFAS materials is primarily the same reason for uses in the IVD reagents which includes material compatibility, inertness, low coefficient of friction, etc. Not having a derogation to produce IVDs using PFAS materials could have a significant impact on the supply of IVD reagents upon the effective date of the Restriction.

4. Prefilled syringe stopper - A device constituent of an integral drug-device combination

Glass prefilled syringes are today widely used within the Union market for health treatments. We estimate that approximately 200+ marketed drugs in prefilled syringes[9] are sold across the European Union annually. Due to their sensitive nature many of these drugs (in prefilled syringes) use a PFAS (ETFE) coated stopper. Examples of indications of these drugs include but are not limited to multiple sclerosis, rheumatoid arthritis, and neutropenia. The PFAS coated stopper plays a key role by providing a barrier effect against extractables from the rubber, minimizing the risk of interaction between the rubber stopper and the Drug during its shelf-life (up to 3-5 years). A well known-example for which a non-coated stopper (PFAS free) resulted in an adverse health effect is the “Eprex” case for which interaction with rubber extractables led to an increased incidence of pure red cell aplasia[10]. For sensitive Drugs substitution of PFAS coated stopper by PFAS free stoppers is not immediately possible. Even if redesign efforts have been initiated there is today no PFAS free stopper available on the market that has the same properties as the PFAS coated stoppers with regards to extractable impurities. With existing PFAS free stoppers, the risk of adverse health effect for sensitive drugs is high as impurities can extract/leachate from the rubber and interact with the Drug through the 3-5 years shelf life. With no derogation the impact of European citizen health will be critical as it will result in Key Drugs shortages (200+ Biologics sold on the EU market with PFAS coated stoppers). No derogation will also have a high impact on innovation and future new drugs launches on the European Market. We estimate that there are approximately 100+ biologic drugs[11] in clinical trials across the European Union that are expected to be launched in a prefilled syringe device with PFAS coated stoppers. A 12 year derogation is at minimum needed as redesign is mandatory and Glass prefilled syringes are highly regulated products: requirements of both, Medical Device Regulation (EU 2017/745) and Human Medicine Directive (2001/83 EC) have to be met when making a change leading to long timelines. Redesign efforts have been initiated but we estimate that more than 12 years are needed for substitution, including, among other, the following steps:

- Stabilities Studies by pharmaceutical companies[12]
- Manufacturing qualification
- Regulatory approval from the device side[13] and the drug side[14]
- Industrial ramp

We estimate that 240 to 480 millions units of PFAS coated stoppers are used on the EU market for marketed drugs and clinical trials across EU. Transformation of this supply capacity will require significant time and investments as all manufacturing equipment will have to be converted to produce PFAS free stoppers, this includes rubber stopper manufacturers and pharmaceutical filling drug lines that will have to be upgraded.

5. Blood Glucose Meters (IVD) for diabetes treatments

Diabetes is one of the big health topics with an incidence of one in eleven adults in the EU. Blood glucose measurements are one of the most important pillars of the therapy, usually performed by the patient. Therefore, many home-use self-analysers, such as the blood glucose meters (BGMs) are designed as affordable appliances. Alternative materials, since they are quite rare, can be very cost intensive, and -

[9] From IQVIA database (https://www.iqvia.com/) -detailed report can be shared upon request
[10] "The increased incidence of pure red cell aplasia with an Eprex formulation in uncoated rubber stopper syringes"-Kidney International, Vol. 67 (2005), pp. 2346–2353
[11] Estimation was made from Global data 2023 (https://www.globaldata.com/) and IQVIA (https://www.iqvia.com/) databases- detailed report can be shared on request.
[12] ICH Q12 Technical and regulatory considerations for pharmaceutical product lifecycle management - Scientific guideline
[13] Notified body Opinion on Annex I of (EU) 2017/745 shall be obtained on the device side of the integral Drug device combination.
[14] Variation to the existing marketing authorization approval

together with lengthy design change and development periods - increase the cost of manufacturing immensely. Identifying a non-PFAS containing alternative, will make the distribution of affordable medical devices for all patients even harder. Patient safety is the first and foremost responsibility of a medical device manufacturer. Therefore, as for basically all medical devices, the design change processes required to change materials are extensive and lengthy. Even if a material with comparable properties is found, the process until it can be registered on the different markets can take several years. This does not include the time of the registration process with the countries itself, which is also time consuming. This again would influence the cost for patients and customers, as well as the healthcare system. Since medical devices make up for a rather small part of material usage worldwide, a restriction of PFAS containing substances within the EU may cause suppliers to terminate their production and hence disrupt the distribution of medical devices within the EU. Additionally, a shortage of possibly alternative materials may arise due to a sudden high demand from several manufacturers. In the end, this affects the patients and customers, because the provision with the respective devices cannot be ensured.

6. Flame retardant properties in patient monitoring equipment

Medical devices are required by the EU MDR to comply with EU safety standards, which include a requirement that plastic parts that are associated with electrical circuits are flame resistant. The choice of plastic is limited as medical devices such as patient monitors and patient ventilators need to be tough and must not easily damaged by for example impacts from hard objects or by being dropped. Impacts can easily occur in emergency situations. Plastics commonly used for medical devices therefore require flame retardants. PFAS such as PTFE are used in plastics as flame retardant and drip protection. The requirements from standards such as IEC 60601-1 and UV-L0 in relation to fire resistance and flammability specify maximum temperature in case of skin contact and have special considerations for oxygen-rich environments due to patients receiving oxygen. Research by members have not found a suitable replacement that is available with the same performance and which is not a regrettable substitution, in particular for material thickness of less than 1mm. The search for alternative materials is a lengthy process and includes obtaining samples of PFAS-free polymers and extruding for testing, redesigning parts, verification and validation, and undergoing comprehensive technical and clinical testing. EU MDR requires strong evidence that new designs do not have a lower level of patient safety or a reduction of clinical benefits as a result of new materials used in the devices. A realistic timetable is needed to allow sufficient time to move to alternatives in conformity of medical regulations.

7. Other case studies illustrating the specific *redesign* challenges

Guidewire for coronary and peripheral interventional application

Guidewires are an integral part of vascular intervention. They are utilized to access target vessels, cross lesions, and deliver other devices that can administer therapy to the target region of the vessel or treat the diseased vessel. Without guidewires, both coronary and peripheral interventional procedures cannot be conducted. Though there are many design requirements for guidewires dependent on the lesion type and clinical presentations, one requirement is universal for all guidewires, i.e., low friction, which allows the guidewires to travel through tortuous vessel to the target lesion without damaging patient tissues. At the distal end of the guidewire, hydrophilic coating can be applied to reduce the friction. However, at the proximal portion of the guidewire, a hydrophobic dry/wet lubricious coating is needed, because the physician needs

to manipulate the wire with their hand during an interventional procedure. The physician cannot manipulate a wire with a fully hydrophilic coating, which either is too slippery when fully hydrated or tacky when the coated surface is not wet. Alternatives to the use of PTFE as the coating on the proximal end of the guidewire have been evaluated multiple times over the past 10 years. In each case, a suitable replacement that could maintain the friction performance of PTFE could not be found unless it is another PFAS coating. The performance evaluation included direct friction measurements as well as in-vitro bench testing where the alternative materials demonstrated inferior performance relative to PTFE coated controls. Percutaneous interventions are premised on accessing and treating a diseased segment of vessel through an access point a distance from the diseased segment. The guidewire is the fundamental tool used by interventionalists to establish the pathway from the access site to the diseased segment. Any redesign of the guidewire coating still needs to meet the basic requirement of guidewire deliverability with minimum resistance in tortuous anatomy and in the delivery of therapeutic devices, while maintaining low profile. Any increase in friction could limit the ability to access complex anatomy or the delivery of therapeutic devices which will limit treatment options for a significant portion of patients that can be treated today. Therefore, a redesign of the guidewire coating will not meet the customer need without a dry lubricious coating.

Printing inks for markings on medical devices and on the device part of an integral drug-device combination

Fluorinated wax is used, by itself or in combination with other waxes as an anti-rub and slip additive in printing inks. These are required for the properties such as slip or lower coefficient of friction, scratch resistance, rub and abrasion resistance, matting effect and hydrophobicity. Printing inks are used to create markings for identification, scale, measurement, size, and other functional attributes on medical devices and on the device part of an integral drug-device combination. The alteration of any of the above listed properties will result in fading away and removal of marking on the device. In case of medical devices such as syringes, inaccurate markings or lack of such markings will result in errors in the medication provided by the healthcare provider because they will not be able to know if the right quantity of the drug has been given to the patient. This will adversely impact the health of the patient due inaccurate amounts of drug administered. The consequences could be lethal. Misidentification of a medical device or drug device combination products in the absence of proper printing inks could result in errors in the treatment of the patient.

There are no currently available known alternatives, which are ready for evaluation through R&D. Once an alternative would be identified for the ink formulation, qualification of the alternative would be required for the mentioned applications. Alternatives will likely require extensive biocompatibility testing and may also require clinical trials, dependent on the application and location of the printing inks. Alternatives may trigger process changes at multiple sites across multiple locations and due to the variety of sophisticated high-volume manufacturing methods, significant process development is anticipated after the formulation is finalized and passes all the biocompatibility testing increasing the substitution timeline. A derogation of 12 years once an alternative is identified is needed to evaluate alternatives, validate, qualify and implement the most promising alternative.

Robotic arms

PFAS (FEP, ETFE, PFA) are used in main cable assembly of robotic arms of an angiography system. Combination of more than 20 individual cables, which are not in contact with patient or user as they are a fixed installation inside the instrument with different functions: high-Voltage cables, power supply cables,

control cables, signal cables etc. Most of the individual cables are multifilament cables. Parts of the cable assembly are heavily and quickly bended when the medical device is in operation.
PFAS are used for insulation action as the thickness of insulation is a key factor of cable assembly bending capability. PFAS substitutes will cause an increase of thickness of the whole cable assembly. Bending performance (bend radius, bend velocity) will decrease and lead to a downgrade of system performance. A thicker cable assembly will no longer fit into the robot construction.
They are also used for their sliding and non-sticking properties, as low friction sliding of the individual cables among each other is essential for the bending capability of the cable assembly. PFAS substitutes (i.e., use of fabric hoses) show poorer sliding properties. Bending performance (bend radius, bend velocity) will decrease and wear will increase. This will lead to a downgrade of system performance, reduced lifetime and reliability of the individual cables. Especially in angiography systems reliability is of maximum importance, as the systems are operating during emergency surgery, and a system failure can be fatal.
Finally, they are used for their flame retardant properties, because fire safety requirements are extremely high for medical systems in clinical environment. The unique characteristic of PFAS is the combination of insulation properties, non-stick properties, mechanical strength and flame retardant properties in one substance. There is no comparable material available to fulfil all these requirements in parallel.
100% substitution will be impossible due to the wide range of outstanding properties of PFAS. Substitution with downgraded system performance and significant change of system design will probably be possible with a 12 year derogation once an alternative has been identified. It is impossible to replace the part until mid-2025. Time for development is not sufficient, no matter how much resources are provided for this task: development of cable assembly with alternative materials, reliability-tests/EMV-tests /safety-test, several iterations to optimize results, approval of product change. Therefore, the product would have to be taken from the market, as only 50% of PFAS in the cable can possibly be replaced prior mid-2030 (in the case where a 5 year derogation is granted), limited to parts of the cable where installation space is not restricted and the movement stress during system operation is less challenging. Some construction redesigns have to be done.
At their end-of-life, the robotic arm is taken back, resold, or upgraded.

Magnetic resonance imaging systems (MRI systems)

PTFE is used in cables and sleeving in low temperatures due for its insolation action, as PTFE has a very low dielectric constant, which means that it does not absorb much energy from electromagnetic fields. This makes it an excellent insulator for use in low-temperature environments, where other materials may be prone to electrical breakdown. In addition, PTFE has a very high dielectric strength, which is the maximum electric field that a material can withstand before electrical breakdown occurs. This property makes PTFE an excellent insulator for use in high-voltage applications, which are common in many low-temperature environments.
PTFE has a very low thermal conductivity which means that it does not transfer heat very well. This is important in low-temperature environments where maintaining a stable temperature is critical. PTFE insulation can help to reduce unwanted heat transfer and maintain a stable operating temperature.
PTFE is highly resistant to chemicals, including most solvents and acids. This makes it an excellent choice for use during manufacturing when the cables may be in contact with other chemicals such as lubricants or adhesives where chemical reactions may be a concern.

PTFE maintains flexibility for cable bending and positioning without cracking during temperature transition from room temperature to extreme low temperature where other materials may become brittle and crack. Such cracks will compromise electrical insulation properties and result in irreparable damage to the magnet system.

At the moment, there is no technical alternatives known with similar properties as PTFE against extreme conditions (low temperature to 4K Celsius). It is impossible to identify suitable alternative materials for the specific working conditions of the applications and completion of all design changes, safety and reliability tests within 2 years. Therefore, the product would have to be taken from the market, and thus, it would reduce the accuracy of diagnosis (e.g., of cancer or neurological disorders), but also the quality of life (impact on monitoring the effectiveness of new drugs/therapies development in pharmaceutical industries).

At their end-of-life, MRI scanners are taken back, refurbished, resold, or they are upgraded, repaired or reused.

Blood Gas Systems

PFAS (PTFE) are used in main cable assembly of varying lengths and conductor count in Blood Gas systems, in special developed detector cable for extra durability in terms of dynamic movements.

Structural Polystyrene Foam is used in instrument housings.

PTFE insulators can be very thin and minimally impact thermal measurements while still providing the necessary electrical insulation around a thermistor or thermocouple component.

PTFE is used to satisfy UL 94 V-0 requirements to self-extinguish and open flame is essential to satisfy fire safety standards for medical equipment.

It is used in mold-release applications to allow molded part to be removed from the mold with fewer ejection pins. This is required to maintain flatness/smoothness specifications for fluidic seals.

Substitution materials do not meet all of the requirements of the current design. Any alternative will downgrade system reliability and endanger clinical availability. No alternative has yet been identified for each application. Given the time required to identify alternatives, approve new vendors, convert old vendors to new suppliers, qualify untested materials, complete engineering verification and clinical validation, there will not be an alternative ready by 2025. As of mid-2023, we continue to discover new places where PFAS is used in the manufacture of our products. Many products are made with vendor proprietary formulations that are found to include PFAS. Plastic molded parts that do not contain PFAS have trace amounts of PFAS found in mold release agents used by the vendor. Electronics production and components continue to identify PFAS in components previously believed to be PFAS-free.

There is no confidence that any of the above products can be certified 100% PFAS free within 2 years.

The main challenges are identifying all PFAS in the supply chain; coordinating with many vendors and design changes simultaneously across all affected products; legacy products on existing last time buy (LTB) inventory must either undergo extensive redesign, or premature end-of-life (EoL); and finding equivalent performance with PFAS-free materials.

When it comes to the end-of-life, instruments can be used for many thousands, or even millions of tests over their service life. Readers are refurbished when returned by customers to be re-sold, re-using the vast majority of parts within them (only swapping out damaged or non-functional parts). Electronics and Printed Circuit Board Assembly (PCBAs) can be recycled.

Multi-use cartridges and Single-use cards are biohazardous waste, which is typically incinerated depending on user laboratory disposal practices, possibility of autoclaving if not incinerated. Instruments not refurbished must be incinerated.
PFAS is in some wiring components, printed circuit board assemblies, moving mechanical assemblies (within hinges, sides, other bearing surfaces), and the structural foam of the enclosure.
Oxygen sensor is deep within the measurement cartridge in a location the user cannot access. Service personnel do not access the biohazardous components, which includes the oxygen sensor.

In-vitro diagnostics devices (IVDs): Laboratory Systems

IVDs are used to detect patient illnesses, infectious diseases and to determine the effectiveness of medical treatment.
PFAS are used for insulation and chemical resistance purposes, as chemical resistance in IVD tubing is of the utmost importance. The use of tubing in IVDs is extensive and varies from product-to-product. If PFAS is present in tubing, but PFAS-free tubing is required in the future, the impact of a change is highly significant. There is a potential presence of PFAS in tubing purchased from suppliers and/or use of PFAS in suppliers' tubing production processes to ensure that chemical resistance is ensured.
If tubing or electronic wire components made of or containing PFAS must be changed, potentially hundreds of IVD laboratory diagnostics devices are impacted, and 100% of the Laboratory Systems portfolio that include automated liquid handling would be affected.
Tubing: The use of tubing in IVDs is extensive, as it is used to transport patient samples through an IVD analyser and to combine the patient sample with chemical substances (reagents). A patient sample is combined with reagents via tubing, resulting in a chemical reaction that a sensor detects. The IVD devices' software is custom-programmed to report the clinical result of the IVD test, based upon the signal generated by the chemical reaction and detected by the sensor.
When tubing contacts patient samples and reagents, IVDs must be tested extensively to ensure that: 1) tubing materials do not cross-react with an individual's patient sample, 2) tubing materials do not cause contamination from one patient sample to another, 3) tubing materials do not cause contamination from one reagent to another, 4) tubing materials used to transport a sample from one device to another device do not result in cross-reactivity or contamination and 5) that software properly interprets and reports patient results. This process is called "validation". If various types of tubing in IVD instruments contain PFAS, but patient results meet product claims registered via medical regulatory authorities, hundreds of unique devices and patient tests must re-validated. The validation could require up to 15 years to complete due to the complexity of validation testing.

Electrical wire insulation: Insulation of electric wires on custom printed circuit boards, power cords and other internal wiring is necessary to: ensure that a specific current must be consistently maintained by the insulated wire component; to protect the wire from heat generated by other parts withing the IVD device; and to ensure that the wire component does not present a heat source that can damage other parts of the IVD device.
If PFAS are used in conjunction with electrical wire insulation, extensive testing will be required if substitute parts have a "like-to-like" performance to ensure the following: 1) expected patient results are maintained (e.g., that no change to insulated electric wires properties occurs), 2) no change to the longevity of parts occurs, 3) no software changes are required as a result of the part change and 4) conformance to

international standards related to electronic products is maintained. If a "like-for-like" replacement of an electronic part is not available, extensive validation of parts with different electronic properties would be required, with a potential timeline of 10-15 years.

Conclusion OR impact:
If the IVD products could not be placed on the market, healthcare institutions would be required to make capital investments for alternative devices. It is not likely that any institution would be able to maintain their current level of care due to costs to purchase new devices elsewhere. In addition, there are certain tests that are unique to the products, if those test were no longer available for devices, patient care would be compromised for certain disease states.
Over 650 million test assays per year in the EU are performed with affected devices. If hospitals and/or patient sample diagnostic laboratories are unable to purchase the IVD devices, alternative tests (assays) for the wide range disease states would not be commercially available and will not meet the high level of accuracy provided by the impacted devices. As a result, patient's conditions may be more difficult to diagnose and treat as other, less suitable methods would have to be used (if they exist). In addition, regulatory body approvals do not allow lower-level performance products to be placed on the market, as such approval would be withdrawn if the adopted parts that do not meet performance claims. As such, this would mean that products which would otherwise support patients from being diagnosed and/or treated, would no longer be able to be placed on the market.

Intensive care devices and systems

The following products have, for example, already been identified as being affected by the PFAS Restriction proposal:

- Intensive care ventilators,
- Anesthesia machines,
- Incubators,
- Patient Monitoring Systems,
- Medical media supply systems,
- Hospital Gas Management Systems.

In these products, fluoropolymers such as PTFE, PVDF, PFA, FKM are essential materials in the following components:

- Hoses, seals and other gas-carrying parts,
- Electrochemical sensors,
- Lubricants,
- Valve coatings.

The materials are indispensable mainly because of their resistance to aggressive media. More specifically:

- Hoses, seals and other gas-carrying parts in medical devices must be permanently resistant to pure oxygen and, for example, anesthetic gases,
- In electrochemical sensors fluoropolymers are used as membranes in strongly acidic electrolytes (e.g., sulfuric acid) or in the electrodes to control their wetting and prevent dissolution. In lead-free oxygen sensors, introduced due to the RoHS Directive, the materials must also withstand free oxygen radicals that would permeate all other plastics.

Furthermore, all electronic components contained in these products rely on semiconductors, the production of which is impossible without PFAS. Producing semiconductors in Europe is a declared goal of the EU Commission. This goal would be thwarted by a comprehensive PFAS ban. At the production plants, components made of fluoropolymers ensure durability, energy savings and safe operation. A broad PFAS ban would result in the unavailability of the necessary production equipment to manufacture the products, including their spare parts.

Emissions:

No emissions of PFAS into the environment are to be expected from these products and the materials they contain. The materials can be considered as harmless to health and as neither fulfilling the criteria of Article 68 of the REACH Regulation nor those of the justification of the present Restriction proposal. According to information from upstream suppliers, the production of the materials is possible without emissions of harmful PFAS chemicals into the environment. This can be ensured by appropriate regulatory measures.

The products are in use for a very long time, in some cases over 20 years. Proper disposal at the end of life is ensured, among other things, by the requirements of the WEEE Directive and other voluntary take-back and recycling offers that go beyond WEEE. In the interests of the circular economy, we would welcome an obligation to return waste to the manufacturer, but this has so far been prevented by European waste shipment regulations. In the pyrometallurgical recycling processes and any incineration of residual waste, the fluoropolymer components are usually thermally destroyed and converted into hydrogen fluoride, which is mineralized as fluoride in the flue gas cleaning process. We are not aware of any emissions of PFASs that are harmful to health from this pathway. Even in the case of deposition, the materials would behave chemically inert in the long term and would not cause emissions to the environment.

Substitution possibilities:

According to the current state of knowledge, there will never be alternative materials that meet all the necessary requirements due to chemical-physical laws. Manufacturers and the regulatory authorities are not prepared to accept any compromises in terms of the functional safety of the products, because human lives depend on it. Due to the high cost, fluoropolymer materials are only used where absolutely necessary.

Derogations:

Only a broad exemption for the use and manufacture of fluoropolymer materials in professional and industrial applications could ensure that all vital products remain available. A specific exemption for the manufacture and use of fluoropolymers (in each case including accessories and spare parts) represents a minimum requirement, but one that appears insufficient for the reasons stated above. Any time limit should at least be designed in such a way that the exemption is reviewed at the end of the time limit and does not lapse without replacement (analog to the RoHS Directive).

The limit values for non-polymeric PFAS in articles must be based on the possibilities of chemical analysis in order to make the Restriction proposal manageable and to avoid legal uncertainties. The limit value of 25 ppb mentioned in the Restriction proposal is far below the measurement limit of the available analytical methods.

Such intensive care equipments like ventilators, anaesthesia devices and neonatal care incubators will no longer be available because less reliable products would not get an approval by the authorities. Equipment already in use at the hospitals would not work anymore after a short period because spare parts could also not be placed on the market anymore. Thousands of patients would most likely die.

Annex 2: Non-exhaustive list of uses of PFAS in medical technologies

Below is a non-exhaustive table of different uses of PFAS in medical technologies (MDs and IVD reageants and instruments):

Uses of PFAS in MDs, and in the device part of integral drug-device combination	Uses of PFAS in IVD reageants and instruments
• Blood contact invasive devices such as e.g., endoscopes, grafts/covered stents, catheter component to improve the device deliverability, catheter tubings for infusion of medication and IV fluids and drug-eluting stent (DES) – blood flow within/between arteries and veins and for DES to control drug release to inhibit the vessel re-narrowing; • Medication contact components - minimise drug-device interactions; • Surgical sutures: pledgets made of PTFE serve as suture abutments when suturing soft tissue. They are essential in heart valve operations; • Fluoropolymers, like PTFE and PVDF, are used in several components for the treatment of serious acute and chronic diseases, and also components such as stents, guidewires, catheters, dilators; • Implantable and invasive medial devices, such as cardiac patches, felts and fabrics; • In hernia meshes for rapid healing of hernia; • Cleaning of medical devices as cleaning solvents in vapor degreasing applications; • Reprocessing devices of medical devices via cleaning, disinfection and sterilization; • Surgical drapes and gowns; • Ophthalmic products (endotamponades- in surgery to reposition a detached retina, eye drops, contact lenses); • Medical tapes and wound dressings; • Medical imaging devices, such as ultrasounds and minimal invasive endoscopes; • Not MD-specific uses in other materials and components such as electrical components and batteries of active medical devices; • Medical equipment for continuous patient monitoring; • Printing inks that are used to create markings for identification, scale, measurement, size, and other functional attributes on medical devices and on the device part of an integral drug-device combination; • Packaging.	• IVD testing kits for haemostasis products that detect blood coagulation; • Heat-transfer agent in IVD clinical chemistry diagnostic testing instruments, which is essential to the functioning of the instrument; • Surfactant properties in *in vitro* diagnostic assays, which allow measures of various parameters such as magnesium concentration in serum, plasma and urine; • Fluoropolymers like PTFE and PVDF are used in several components for analytical instruments; • Others: Coating on the dispense tip, tubing and tubing connectors, distributors, plugs, washers, seals and gaskets, syringe pump valves, O-rings and sealants, fittings, PTFE coated tank, dry lubrication of moving mechanical parts, manufacturing equipment, without which the assays cannot be manufactured, filtration media; • Packaging.

For a more exhaustive list of medical technology uses, please consider MedTech Europe's input to the public consultation on the PFAS Restriction proposal, Part 33.

Annex 3: Non-exhaustive list of types of PFAS used in medical technologies

Below is a non-exhaustive table of different types of PFAS used in medical technologies (medical devices and IVD reagents and instruments):

Types of PFAS used in MDs, and in the device part of integral drug-device combination	Types of PFAS used in IVD reagents and instruments
• PTFE; • FEP; • Perfluoropolyether; • PVDF; • PVDF-HFP; • Perfluorinated acrylates (C6 – C14); Hydrophobic surface treatments – surface bound or reacted fluoropolymers of undisclosed composition; • PTFE coatings • Specialty fluorinated lubricants; • FKM/FPM fluoroelastomers; • FFKM/FFPM perfluoroelastomers; • PTFE and PVDF suture materials; • Semifluorinated alkanes (for example 1-(Perfluorhexyl)octane and 1-(Perfluorobutyl)pentane).	• PTFE; • FEP; • PVDF; • FKM/FPM fluoroelastomers; • FFKM/FFPM perfluoroelastomers; • PCTFE; • ETFE; • Hexafluor propanol; • Trifluoroacetic acid; • Trifluoroacetic acid anhydride; • Trifluoromethane-sulfonic acid anhydride ; Trifluorotoluene; • Methyl trifluoromethanesulfonate.

For a more exhaustive list of medical technology uses, please consider MedTech Europe's input to the public consultation on the PFAS Restriction proposal, Part 33

Note: As mentioned above, the medical technology sector is a downstream user of materials and components. Companies have been working with their suppliers to map the uses of PFAS in medical technologies and continue to find new uses over time. The EU REACH Restriction proposal for per- and polyfluoroalkyl substances (PFAS) includes over 10,000 PFAS substances, including polymers. Many of these substances are currently not regulated under existing hazardous substance legislation under the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) or in European legislation. Due to the grouping approach and the long list of PFAS substances, this runs the risk that in the future, new uses of PFAS will be found, which are not covered by one of the derogations and then will not be permitted.

Annex 4: Overview of the design cycle steps required for a medical technology

High-level required steps:

Step 1: Generic testing

Finding an alternative, that performs as well as or better than the former substance/material/technology:

- Changing to an alternative material must follow medical device regulations
- Evaluate feasibility for alternate options, product development, verification/validation, aging testing, biocompatibility testing, pre-clinical studies, clinical trial, and regulatory submissions and approvals
- 10+ years to redesign per impacted product; multiple product changes will result in longer timelines from testing to selecting an alternative (see below for detailed steps)

Step 2: Specific device testing (indicative best-case timings)

- Material feasibility testing (incl. pre-clinical, animal safety testing and design verification) – at least 1 year
- Sample testing / making parts for testing, including industrialisation / Change of manufacturing processes and tools – at least 1 year
- Formal Verification & Validation (V&V) testing – at least 1 year
- Biocompatibility testing – at least 6 months up to 2 years dependent on the device type
- Clinical phase submissions/approvals – at least 6 months
- Clinical trial enrollment – at least 2.5 years
- Clinical trial follow-up – at least 1 year
- Clinical trial report – at least 3 months
- Quality Lab
- Regulatory submissions – at least 1 year
- CE regulatory approval – at least 18-24 months; 5-26 months if for the rest of the world (regulatory approval timing assumes regulatory bodies could support these product submissions *without delays*)
- Procurement time – at least 1-3+ years[15]

High-level required steps	Exemplary process steps required depending on scope of individual materials require replacement
Identify potential materials and supplier for alternatives	Evaluate new material(s) based on: - Material properties (e.g., electrical resistivity, tensile strength, durability, chemical resistance, temperature resistance, biocompatibility, etc.) - Intended use/function of material (one alternative may not be suitable for all application) Evaluate Suppliers: - Supplier capabilities & costs

[15] This could be highly variable, depending on the Technology Readiness Level of the material, which is especially relevant if a new substance has to be invented to replace the given PFAS. For example, if the new substance has only been synthesized at lab-scale, then the upstream supplier may spend years on scale-up, to make the substance available at a commercial production scale. Ideally, an alternative could be identified which is already available commercially, butthis cannot be ensured for PFAS, and all uses.

	- Suppliers Quality Management Systems (QMS) & Documentation to ensure traceability - System integration feasibility in Entreprise Resource Plannig (ERP) system for data exchange

Define/Select potential alternative(s) material/supplier and frame project	- Select material or multiple alternatives by balancing risks on costs and timeline for testing
	- Establish project plan & test plan to define resources to introduce alternative material
	- Secure project funding & resources for material testing & implementation:
	  o Management buy in for decision (constraints depending on financial capabilities and availability of resources)
	  o Technical project lead
	  o Supplier (capability to provide sample for testing)
	  o R&D (evaluate risks for contamination and/or suitability of material used)
	  o Manufacturing for functional testing
	  o Regulatory for impact on global registrations
	- Initiate change control process and collect stakeholder inputs:
	  o Evaluate Regulatory constraints
	  o R&D
	  ▪ Evaluate scope & documents required update due to material change (risk management)
	  ▪ Define test lab
	  ▪ Initiate risk assessment for new material Design Failure Mode and Effect Analysis (DFMEA)/ Process failure mode and effects analysis (PFMEA)
	  o Manufacturing
	  ▪ Evaluate risks and establish conditions for functional testing to evaluate alternatives without impacting regular production (risk for contamination and other control measures required for test execution)
	  o Procurements & Software Quality Assurance (SQA)
	  ▪ Setup new supplier

Test alternative(s)	- Produce parts for testing - Prepare test setup - Identify Quality lab and contract new lab if required (NDA where required) - Formal V&V process: Execute testing and evaluate manufacturing process capabilities

	- If required, return manufacturing condition to regular production after functional & V&V testing until test outcome (>3 month lead time if Biocomp and Packaging Tests are additionally required to simulate material stability and behavior on long term performance). - Biocompatibility tests including extractable and leachanle test
Select & Implement alternative	Execute Change Control Process - Approve alternative material - Approve and implement new supplier (agree on contract and condition) - Update technical documentation (drawing, DMFEA/PFMEA, technical summary files, IFU, labeling, material specification, etc.) - Update of manufacturing procedures & process (Design transfer), if needed update or source/setup production equipment - Update IFU & Labeling update or register new product - Regulatory product registration if required (510k, CE and others where required) - Initial sample testing - Market release (Customer training, Marketing campaign etc.) - Compliance assessment of new material and local requirements for substances

Annex 5: PFAS and Fluoropolymers Emissions Bibliography

1. C.D Campbell, D.H Brooks, M.W Webster and H.T Bahnson, *The use of expanded microporous polytetrafluoroethylene for limb salvage: a preliminary report*, May 1976, National Library of Medicine, available at: https://pubmed.ncbi.nlm.nih.gov/1265654/
2. Shih-Chao Hsu et *al.*, *Assessing the Safety of Expanded Polytetrafluoroethylene Synthetic Grafts in Living Donor Liver Transplantation: Graft Migration Into Hollow Viscous Organs - Diagnosis and Treatment Options*, July 2017, Med Sci Monit., available at: https://pubmed.ncbi.nlm.nih.gov/28683053/
   Conclusion - ePTFE use in LDLT [liver donor liver transplant] continues to have wide safety margin, with a complication rate of only 1.52%
3. Luis J. Zurera et *al.*, *Safety and efficacy of expanded polytetrafluoroethylene-covered transjugular intrahepatic portosystemic shunts in children with acute or recurring upper gastrointestinal bleeding*, March 2015, Pediatr Radiol, available at: https://pubmed.ncbi.nlm.nih.gov/25430967/
   Conclusion - safety and efficacy of expanded PTFE-covered TIPS were satisfactory in this small series of children with acute or recurrent GI bleeding
4. Scott Shadfar et *al*, *Safety and Efficacy of Expanded Polytetrafluoroethylene Implants in the Surgical Management of Traumatic Nasal Deformity*, August 2015, JAMA Otolaryngol Head Neck Surg., available at: https://pubmed.ncbi.nlm.nih.gov/26110468/
   Conclusion - ePTFE implants can be used at the level of the nasal dorsum…with a low risk of complications
5. A.M Belousov et *al., Safety of mesh with fluoropolymer coating during intra-abdominal placement in large animals: results of the pilot study*, 2023, Khirurgiia (Mosk), available at: https://pubmed.ncbi.nlm.nih.gov/36748870/
   Conclusion - implanted, fluoropolymer coated prostheses did not cause any clinically significant adverse reactions or complications
6. Elliot Pressman et *al., Teflon™ or Ivalon®: a scoping review of implants used in microvascular decompression for trigeminal neuralgia*, February 2020, Neurosurg Review, available at: https://pubmed.ncbi.nlm.nih.gov/31786660/
   Conclusion – Teflon is an effective material for treatment of long-term symptoms related to trigeminal neuralgia
7. XIENCE, *Examples of implantable PFAS*
8. Lloyd J. Winchell et *al.*, *Per- and polyfluoroalkyl substances thermal destruction at water resource recovery facilities: A state of the science review*, 2020, Wiley Online Library
9. EPA, *Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances*, December 2020
10. Carl Hanser Verlag, *Closing the Recycling Loop, Up-Cycling of End-of-Life Fluoroplastics* ,June 2014, Kunstsoffe International
11. PlasticsEurope, *Guide for the Safe Handling of Fluoropolymer Resins*, November 2012
12. Shivangi Sharma et *al.*, *Biocompatible Polymers and its Applications*, 2020, Elsevier
13. Charles Baquey et *al.*, *Fluorinated Biomaterials for Cardiovascular Surgery*, INSERM

14. David W. Grainger, *Fluorinated Biomaterials*, 2011
15. Fang Liu and David W. Grainger, *Fluorinated Biomaterials*, 2011
16. Arnold S. Breitbart and Valérie J. Ablaza, *Implant Materials*, Chapter 7, Grabb and Smith's Plastic Surgery, 2007
17. J. Bakker, B. Bokkers and M. Broekman, Per- and polyfluorinated substances in waste incinerator flue gases, RIVM report, 2021
18. Barbara J. Henry et *al.*, *A critical review of the application of polymer of low concern and regulatory criteria to fluoropolymers*, Integrated Environmental Assessment and Management, February 2018, available at: https://setac.onlinelibrary.wiley.com/doi/10.1002/ieam.4035
19. Stephen H. Korzeniowski et *al.*, *A critical review of the application of polymer of low concern regulatory criteria to fluoropolymers II: Fluoroplastics and fluoroelastomers*, Integrated Environmental Assessment and Management, June 2022, available at: https://setac.onlinelibrary.wiley.com/doi/10.1002/ieam.4646
20. Aleksandrov et *al.*, *Waste incineration of Polytetrafluoroethylene (PTFE) to evaluate potential formation of per- and Poly-Fluorinated Alkyl Substances (PFAS) in flue gas*, Chemosphere, 2019
21. Ammar A, et *al.*, *Neural tissue compatibility of Teflon as an implant material for microvascular decompression*, Neurosurgical Review Vol 13, 1990, pp. 299-303
22. Anderson BVC et *al.*, *Trends in polymer development*, Science, 1980, pp. 208, 626
23. Barber HD et *al.*, *Using a dense PTFE membrane without primary closure to achieve bone and tissue regeneration*, Journal of Oral Maxillofacial Surgery, Vol 65, 2007, pp. 748-752
24. Bartee BK and Carr JA, *Evaluation of a high-density polytetrafluoroethylene (n-PTFE) membrane as a barrier material to facilitate guided bone regeneration in the rat mandible*, Journal of Oral Implantology, Vol 21(2), 1995, pp. 88-95
25. Bartee BK, *The use of high-density polytetrafluoroethylene membrane to treat osseous defects: Clinical reports*, Implant Dentistry, Vol 4(1), 1995, pp. 21-26
26. Calnan J, *The use of inert plastic material in reconstructive surgery*, British Journal of Plastic Surgery, Vol 16, 1963, p. 1
27. Curry PT et *al.*, *Chromosomal aberrations in Chinese hamster ovary (CHO) cells conducted with test article extracts*, IPE-NAMSA PTFE Vascular Graft Biocompatibility Report, 2005
28. Dunn DS et *al.*, *Cytotoxicity study using the agarose overlay method (solid)*, IPE-NAMSA PTFE Biocompatibility Report, 2005
29. Durucu C et *al.*, *Medialization laryngoplasty with Gore-Tex: An animal study*, Journal of Voice, 3 July 2006
30. Friedneberg ZB, *Bone growth into Teflon sponge, Surgery, Gynecology and Obstetrics*, Vol 116, 1963, p. 588
31. Gourlay SJ et *al.*, *Biocompatibility testing of polymers: In vivo implantation studies*, Journal of Biomedical Materials Research, Vol 12, 1978, p. 219
32. Harrison JH, *The use of Teflon as a blood vessel replacement in experimental animals*, Surgery, Gynecology and Obstetrics, Vol 104, 1975, p. 81
33. Homsy CA, *Biocompatibility of perfluorinated polymers and composites of these polymers, Biocompatibility of Clinical Implant Materials*, Williams OF, ed., Chap. 3 Vol II, 1982, pp. 59-77

34. Homsy CA and Anderson MS, *Functional stabilization of soft tissue and bone prostheses with a porous low modulus materials system, Biocompatibility of Implant Materials*, Williams DF, Ed., 1976, Chap. 10
35. Homsy CA et *al.*, *Rapid in vitro screening of polymers for biocompatibility*, Journal of Macromolecular Science, Chemistry, Vol 3, 1970, pp. 615-634
36. Lamb JW et *al.*, *A comparison of porous and non-porous Teflon membranes plus demineralized freeze-dried bone allograft in the treatment of class II buccal/lingual furcation defects: A clinical re-entry study*, Journal of Periotology, Vol 19(12), 2001, pp. 1580-1587
37. Lindberg PB et *al.*, *A new experimental model for studies of local inflammatory reactions*, Swedish Dentistry Journal, Vol 15(5), 1991, pp. 235-243
38. Rice RM et *al.*, *Biocompatibility testing of polymers: In vitro implantation studies with in vivo correlation*, Journal of Biomedical Materials Research, Vol 12, 1978, p.43
39. Sullivan B et *al.*, *Stabilization of Thompson femoral head prosthesis with a porous stem coating: A case report*, Clinical Orthopedics, Vol 132, 1978, p. 136
40. U.S. Food and Drug Administration, *Minutes of Panel Hearings, General and Plastic Surgery Devices Classification Panel*, Washington DC, 24 March 1978
41. Von Recum AF et *al.*, *Biocompatibility tests of components of an implantable cardiac assist device,* Journal of Biomedical Materials Research, Vol 12, 1978, pp. 743-765
42. Wilsnack RE et *al.*, *Human cell culture testing of medical devices and correlation to animal tests, Biomaterials*, Medical Devices and Artificial Organs, Vol 1, 1973, pp. 543-562
43. Wilsnack RE, *Quantitative cell culture biocompatibility testing of medical devices and correlation to animal tests*, Biomaterials, Medical Devices and Artificial Organs, Vol 4, 1976, pp. 235-261
44. Wood JA, et *al.*, *Acute systemic toxicity*, IPE-NAMSA PTFE Vascular Graft Biocompatibility Report, 2005
45. Wood JA, et *al.*, *Intracutaneous toxicity*, IPE-NAMSA PTFE Vascular Graft Biocompatibility Report, 2005
46. Wood JA et *al.*, *Ocular irritation study in the rabbit*, IPE-NAMSA PTFE Vascular Graft Biocompatibility Report, 2005
47. Joint Research Center, *Supply chain analysis and material demand forecast in strategic technologies and sectors in the EU – A foresight study*, March 2023, available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC132889
48. GSI Environmental, *Technical Support Document in Response to ECHA Annex XV Restriction Proposal for PFAS*, Gujarat Fluorochemical's RAC Comment Letter, June 2023
49. Produkt Kanzlei, Legal Observations, *Proposal for a restriction of Per- and polyfluoroalkyl substances (PFAS) according to Regulation (EC) No. 1907/2006 (REACH)*, March 2023
50. Dr. Gehrmann et al., *Pilot-Scale Fluoropolymer Incineration Study: Thermal Treatment of a Mixture of Fluoropolymers under Representative European Municipal Waste Combustor Conditions*
51. Stefen H. Korzeniowski et al., *A critical review of the application of polymer of low concern regulatory criteria to fluoropolymers II: Fluoroplastics and fluoroelastomers*, Integrated Environmental Assessment and Management, June 2022, available at: https://setac.onlinelibrary.wiley.com/doi/full/10.1002/ieam.4646?af=R