CHFCA
Clean. Efficient. Energy.

2900-550 Burrard St.
Vancouver, BC
V6C 0A3

P: (604) 283-1040
F: (604) 632-4910
www.chfca.ca

July 19, 2023

Environment and Climate Change Canada
Program Development and Engagement Division, Science and Risk Assessment, Science and Technology Branch
351 Saint-Joseph Boulevard
Gatineau, Quebec
K1A 0H3

Attention: Program Development and Engagement Division
Sent via email: mailto:eccc.substances.eccc@canada.casubstances@ec.gc.ca

Dear Program Development and Engagement Division,

Subject: Canada Gazette, Part I, Volume 157, Number 20, May 20, 2023: Publication of the draft state of per- and polyfluoroalkyl substances (PFAS) report and Risk Management Scope

The Canadian Hydrogen and Fuel Cell Association (CHFCA) is pleased to provide comments on the publication of the proposed draft State of Per- and poly-fluoroalkyl Substances (PFAS) report. This report, in our understanding, provides a qualitative assessment of the fate, sources, occurrence, and potential impacts of PFAS on the environment and human health to inform decision-making on PFAS in Canada: Canada Gazette, Part 1, Volume 157, Number 20: GOVERNMENT NOTICES.

The recent shift from the establishment of incremental emissions targets to global net-zero targets has brought hydrogen from a niche technology to the forefront of discussions around energy policy options to displace polluting forms of energy and, in turn, help reduce greenhouse gas emissions to achieve carbon neutrality by 2050. Hydrogen-based fuels are forecasted to grow more than 140% by 2030 to 212 Mt, according to the International Energy Agency.

In the Canadian context, according to a report by EY, hydrogen's total Canadian annual market potential could reach $100 billion and create up to 350,000 jobs by 2050. In addition to the industry's economic benefits, the Government of Canada estimates that the sector will assist with reducing Canada's emissions by 45 million metric tonnes annually by 2030 and up to 190 million metric tonnes annually by 2050.

Under this proposal, the class of over 4,700 human-made substances (PFAs)[1] would meet one or more criteria in section 64 of the 1999 Canada Environmental Protection Act (EPA), which defines a substance as "toxic" if it is entering or may enter the environment in a quantity or concentration under certain conditions, e.g., creating an immediate or long-term harmful effect on the environment or its biological diversity. Fluoropolymers, often classified as PFAS, are specialty plastics that, in essence, underpin hydrogen and fuel cell systems as they are used to manufacture hydrogen-related products, components, and technologies that are critical to the development of hydrogen and fuel cells.

CHFCA is a national industry association providing a unified voice for the hydrogen sector in Canada. The Association represents over 180 world-leading Canadian organizations that provide technologies at all stages of the hydrogen value chain: end users, producers, distributors, equipment, technology, utilities, and service providers. Fundamentally, the issue the industry seeks to solve is environmental, and, thus, it has a 100-year history of producing ground-breaking technologies while at the same time being mindful of and, ultimately, improving health and safety and reducing our environmental footprint.

The CHFCA's main concern with the proposed conclusion, which is that PFAS as a class should be added to the list of toxic substances in Schedule 1, is the following: **Fluoropolymers, a PFAS, is essential to manufacturing hydrogen-related products – especially fuel cells – as there currently aren't commercially viable alternatives that have as desirable physical and chemical characteristics as the substance.**

We are providing our feedback to highlight the importance of a specific PFAS, Fluoropolymers, to the hydrogen and fuel cell sector, and **we hope this proposed action will not be a precursor to an outright ban of PFAS, before suitable alternatives are commercially viable. While CHFCA agrees that there needs to be a swift development of commercially viable alternatives, an outright ban at this moment would jeopardize the scale of this nascent industrial sector.**

[1] "Per-and polyfluoroalkyl Substances (PFAS)," Health Canada (Government of Canada), https://www.canada.ca/en/health-canada/services/chemical-substances/other-chemical-substances-interest/per-polyfluoroalkyl-substances.html.

I. PFAS and its relevance for the hydrogen and fuel cell sector

Per- and poly-fluoroalkyl substances (PFAS) are a large, complex group of synthetic chemicals or high molecular weight solid plastics used widely in industry and consumer products. As they contain strong carbon-fluorine bonds and impart other desirable properties, they do not degrade easily in the environment. There are over 4,700 PFAS types, and these chemicals all have distinct physical and chemical properties, health, and environmental profiles, uses, and benefits[2].

This class of chemicals is categorized into polymers and non-polymers. The two classes of non-polymer chemicals are per- and poly-fluoroalkyl substances, and the three classes of polymer substances are fluoropolymers, perfluoropolyethers, and side-chained fluorinated polymers.

Relevance of PFAS to the sector

Fluoropolymers are a group of PFAS polymers, or, in other words, a family of specialty plastics that provide a solid foundation for hydrogen and fuel cell systems. They are used principally in proton-exchange membrane (PEM) electrolyzers and PEM fuel cells, which are energy conversion technologies indispensable to producing and storing large amounts of hydrogen power without carbon dioxide emissions.

Polytetrafluoroethylene (PTFE), fluorinated ethylene propylene (FEP), ethylene tetrafluoroethylene (ETFE), and tetrafluoroethylene copolymers with perfluoroalkyl vinyl ethers (e.g., perfluoroalkoxy polymer, PFA) account for approximately 70% to 75% of the world fluoropolymer consumption[3]. PTFE makes up 58% of worldwide fluoropolymer consumption[4].

The desirable properties of fluoropolymers include durability, mechanical strength, inertness, thermal stability in foreseeable use conditions, and resistance to chemical, biological, and physical degradation. To highlight the importance of fluoropolymers to hydrogen and fuel cell development, the following is a list of hydrogen-relevant fluoropolymers use in different stages of the value chain, with PEM electrolysis and PEM fuel cells being the most relevant from a PFAS perspective:

---

[2] 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* 14, no. 3 (March 30, 2018): 316–34, https://doi.org/10.1002/ieam.4035.

[3] Henry et al. (n 2) 317.

[4] ibid.

A. PEM Water Electrolyzers:

The membrane is a critical component of membrane electrode assemblies (MEA), which is the core of PEMs. The membrane plays many important roles, such as isolating the anode and cathode from each other, acting as the electrolyte, and conducting protons from the anode to the cathode.

To manufacture these membranes, materials providing the best conductivity, chemical stability, and mechanical strength are ionomers. Membranes consist of ionomers, which are perfluorinated copolymers that, in this case, carry sulfonic acid groups so they can act as ion exchangers. The mechanics of the ionomers are relatively poor, so almost all current membranes include a polymer reinforcement, most commonly polytetrafluoroethylene (PTFE).

PTFE is filled with the ionomer to which layers of pure ionomer are attached, and each ionomer consists of a highly hydrophobic PTFE backbone and hydrophilic side chains, each terminated with a sulfonic acid group. The hydrophobic PTFE backbone provides mechanical stability, whereas the sulfonic acid groups form interconnected domains with the absorbed water and are responsible for the conduits for proton transport.

B. PEM Fuel Cells (PEMFC):

As mentioned above, PEMs are a crucial part of fuel cells as they produce the electrochemical reaction necessary to permit only the necessary ions to pass between the anode and cathode in a fuel cell. Anion exchange membrane fuel cell technologies use similar types of fluoropolymers as those used in PEM technologies. Below is an explanation of the importance of PFAS in manufacturing the heart of PEMFCs, the MEA.

a. Gas Diffusion Layers (GDL):

- GDLs are thin, porous sheets responsible for gas and water transport in any PEM fuel cell. A GDL consists of carbon fibre paper or felt. In PEM fuel cells, water retention (at the cathode side) can result in lower power generation, and to ensure water balance in the fuel cell stack and, ultimately, make the operation of the fuel cell possible, the GDL substrate is treated with PTFE as a hydrophobic agent.

b. Catalyst Layers:

- Catalyst layers are the sites at which the electrochemical reaction occurs. A layer of catalyst is added on both sides of the membrane-one on the anode layer and another on the cathode layer. Conventional catalyst layers include particles of platinum dispersed on a high-surface-area carbon support. This catalyst is mixed with a perfluorinated sulfonic acid (PFSA) ionomers and is squeezed between the membrane and the GDLs.

- Ionomers in these layers must be able to mechanically and chemically withstand the harsh conditions typical of fuel cell operation, and PFSA ionomers have high proton conductivity and excellent mechanical-chemical stability to withstand these conditions.

- PFSA Ionomers play several key roles in catalyst layers and inks, which includes carrying protons to and from the triple phase boundary in catalyst layers, transporting water in catalyst layers, and functioning as a binder in catalyst inks to enable the dispersion of catalyst powders.

c. "Microporous layer" (MPL):
   - GDLs are also equipped with a layer in addition to the GDL substrate, known as an inner surface, called a "microporous layer" (MPL), primarily to reduce the contact resistance between the catalyst layer and GDL. The MPL is partially coated with PTFE to control the two-phase flow of liquid water, and thus water management is established between the catalyst layer and the macroporous substrate, the GDL substrate, in this case.

d. Electrodes
   - The electrodes, which are attached to the membrane, contain a certain amount of fluorinated ionomer. The identity and quantity present are specific to the water management requirements within the MEA, ionic conductivity, chemical degradation resistance, and binding capability to the adjacent and internal components.

C. Infrastructure for hydrogen transport and storage:

In gas grids, fluoropolymers (PFSA ionomers and PTFE) are key materials used in mechanical compression, electrochemical compression (PEMs), cryogenic impression, and volumetric compression.

PTFE, in the form of nylon bands, is used in a variety of hydrogen refueling station applications, e.g., valves, flow meters, and dispensers. PTFE's essential characteristics, such as their high wear resistance, low coefficient of friction, and moderate hardness, make them optimal for seal pipe and fittings connections.

Fluoropolymers, such as EFTE and PFA, are used in addition to PTFE to transport gaseous and liquid hydrogen by road and water and to store onshore bulks of liquid hydrogen. PTFE materials are the most common type used in reciprocating compressor pistons, riders, and packing rings to achieve sufficiently low friction and a long lifetime.

D. Sealing Materials

Significant thought needs to be put into the components for deployment in fuel cells. In the case of sealing fuel cells, typical sealing materials include fuel cell gaskets, spacers, and end plates. Incorrect fuel cell gaskets and end plates, for example, can lead to gas leaks and insufficient fuel cell stack compression.

PTFE-based gaskets are an important and commonly used component for a fuel cell as they work as a sealing agent in the stack assembly. This material type is relatively inexpensive, is easy to shape into gaskets, provides the correct compression needed, and acts as a 'barrier' for potential fuel leaks, which helps in maximizing the highest possible efficiency.

E. Chloroalkali Electrolysis

The industrial electrolysis sector typically uses a membrane in the chloroalkali electrolysis process too. However, unlike PEM electrolysis, the membrane is based on two layers: a perfluoro sulfonic acid ionomer and a perfluoro carboxylic acid (PFCA) ionomer. Perfluoro carboxylic and sulfonic acids are compounds that belong to the class of PFAS.

The development of the membrane cell in the past 60 years has eliminated the need to use mercury cell process and diaphragm cell process, which are environmentally unfriendly processes due to their use of mercury and asbestos, respectively.

Potential alternatives to the fluoropolymers used in the H2 value chain

Much like how the membrane cell process replaced the environmentally harmful mercury cell process in the chloroalkali industry, the CHFCA recognizes the need to find viable alternatives to fluoropolymers.

In the case of membranes, research on fluorine-free ionomers and membrane materials has been ongoing for decades. Pemion® is a PEM breakthrough of CHFCA member company Ionomr which has all the properties necessary to displace PFSA with environmentally benign hydrocarbon materials. Pemion® has achieved performance and durability testing results that surpassed internationally recognized standards from the US Department of Energy (US DOE) and Hydrogen Europe[5]. Pemion® is a promising product ready for widespread deployment in heavy-duty fuel cell applications; other non-fluorinated membrane concepts are also currently available from suppliers, and their deployment must be promoted to replace the current perfluorinated compounds as early as possible. However, many hydrocarbon membranes available still have poor durability,

---

[5] "Ionomr Innovations' Pemion® hydrocarbon-based proton exchange membrane and polymer exceed industry durability targets," Ionomr Innovations, January 29, 2023, https://ionomr.com/wp-content/uploads/2023/01/Pemion-Durability-Data_News-Release-and-Technical-Backgrounder_For-Release-Jan19.pdf.

are not produced in high enough volumes, and are still immature, lasting only dozens of hours against lifetime requirements of >25,000 hours.

There are promising developments of reinforcement materials to replace the PTFE with fluorine-free compounds like electrospun polybenzimidazole materials. However, the commercial use of these reinforcements is expected to begin not before five to ten years, also motivated by superior mechanical properties compared to those of PTFE.

Concerning the GDL, Hydrophobisation of the GDL is today achieved using PTFE. The PTFE treatment of the GDL cannot easily be replaced as there currently aren't viable alternative hydrophobising agents as durable as PTFE.

On sealing materials, the harsh environment and sensitivity of the MEA to contamination punctuates the need for very stable sealing materials. Fluorine-free-elastomers are alternatives under evaluation, but contamination of the MEA, which limits its lifetime, and the material's susceptibility to oxidative deterioration, are issues. Limited amounts of graphene and flexible graphite have been tested to substitute fluoropolymers in sealings, gaskets, and wedges. However, such products in the form of metal sheets would sacrifice chemical resistance if they were to be used to add strength and would increase the cost significantly while limiting uses in key sectors.

In water electrolysis, alkaline electrolysis can provide a PFAS-free pathway. Canadian CHFCA members Next Hydrogen and Hydrogen Optimized are developing unique capabilities in this space that may also allow for dynamic response and interconnection with renewables. While alkaline electrolysis provides a potential PFAS-free solution, there are other advantages to PEM electrolyzers. Both technologies are at a pivotal time in their development and scaleup, with their own advantages and disadvantages. From a capacity perspective, the sector needs every electrolysis solution available today. Competition and innovation in the space will ensure that both PEM and alkaline electrolyser technologies continue to improve, both from performance and environmental perspectives.

There are other promising earlier-stage electrolysis solutions, which may offer a viable PFAS-free pathway. This is the case of anion exchange membrane electrolyzers, with Canadian companies such as Cipher Neutron leading in this area's development.

In short, fluoropolymers are challenging to replace in the near-term future due to the lack of alternatives currently that can impart all the necessary properties to displace these substances and, at the same time, are commercially viable and mature for wide-scale deployment. The promise of innovations, like Pemion®, nonetheless, that are currently on the market, albeit at a small scale, shines a light on the opportunity to advance health and safety in the industry by developing new eco-friendly alternatives.

Other promising innovations include the development of electrochemical energy recycling and re-manufacturing processes to ensure circularity in the production and use of perfluorinated substances and other materials commonly used in the industry. With a global scarcity of critical minerals, for example, that compose MEAs, such as platinum, iridium, and ruthenium, and an increased demand for ionomers needed to vastly scale up hydrogen production to meet Canada's environmental targets combined with the need to minimize our environmental footprint, it is imperative to recycle and re-manufacture electrochemical energy technologies to make their life cycle as sustainable as possible. The University of Toronto is establishing a team focused on electrochemical energy recycling and re-manufacturing to develop, test, and validate recycling and remanufacturing processes, as well as to design new materials and architectures for recyclability. By establishing this leadership in a field that is in its infancy internationally, Canada could not only lead, but fundamentally shape this emerging field of research.

II. Scientific research on PFAS' toxicological effects in the broader context

The reports of environmental and human health impacts of PFAS have increased significantly in peer-reviewed literature. The CHFCA acknowledges that just like other chemicals, PFAS could produce a wide range of adverse health effects depending on the circumstances, exposure, and factors associated with the individuals exposed to PFAS. The harmful impacts on human health most consistently observed from PFAS exposure are immune suppression, changes in liver function, elevated liver enzymes, and lower birth weight[6].

Epidemiological studies of PFAS toxicity in humans have also revealed associations between exposure to specific PFAS and additional health effects, such as kidney disease, adverse reproductive and developmental outcomes, diabetes, and cancer. For example, authoritative reviews have considered the carcinogenic potential of PFAS, and the International Agency for Cancer Research has classified perfluoro octane sulfonate (PFOA) as possibly carcinogenic to humans. A 2018 Blake and colleagues study found an association between decreased glomerular filtration rate and serum PFAS[7]. Also, a 2018

[6] "Our Current Understanding of the Human Health and Environmental Risks of PFAS | US EPA," US EPA, June 7, 2023, https://www.epa.gov/pfas/our-current-understanding-human-health-and-environmental-risks-pfas.

[7] Blake E Bevin et al. "Associations between Longitudinal Serum Perfluoroalkyl Substance (PFAS) Levels and Measures of Thyroid Hormone, Kidney Function, and Body Mass Index in the Fernald Community Cohort," *Environmental Pollution* 242 (November 1, 2018): 894–904, https://doi.org/10.1016/j.envpol.2018.07.042.

Wang and colleagues study found an association between perfluoroalkyl substance (PFAS) exposure and diabetes risk[8].

At the same time, the state of scientific research on the toxicological effects of PFAS has some limitations and has shown conflicting points of evidence and conclusion in the case of fluoropolymers exposure. First, it must be noted that much of the current toxicity data for PFAS are primarily for legacy PFAS, specifically "long-chain" PFAS, perfluorooctanoic acid (PFOA), and perfluoro octane sulfonate (PFOS)[9], which to a large extent, have been replaced by "shorter-chain" PFAS in commerce. As defined in the previous section, PFAS comprise a large class of over 4,700 chemicals with diverse molecular structures and physical, chemical, and biological properties, health, and environmental profiles, uses, and benefits. Declaring an entire class of 4,700 PFAS as CEPA "Toxic" when most of the available data are for two specific PFAS and without conducting a risk assessment of smaller related groups of PFAS would be a broad generalization of the class and an inexact classification of PFAS chemicals.

Reviews of existing epidemiological studies have found a gap in scientific research on PFAS' toxicological effects: confounding factors as a cause of these health effects. Opposing types of causation must be considered, and other types, such as comorbidities, can also cause different health outcomes[10]. Human toxicokinetics appears to vary as they take place in two usually opposite directions, health effects and "no health effects," with changing kidney function, leading to nonmonotonic dose-response relationships and, possibly, errors in estimating associations[11]. Determining whether PFAS chemicals specifically cause health effects in humans and at what levels are active areas of research that need to be established and conducted before classifying all these chemicals as EPA "toxic."

In existing epidemiological research, there is a ubiquity of conflicting points of evidence and conclusion on the toxicological effects of exposure to fluoropolymers. A 2018 Henry and colleagues study found that fluoropolymers, including PTFE, meet the "polymers of low concern" (PLC) criteria[12]. Although fluoropolymers are persistent, they do not possess characteristics, like immobility or low molecular weight, that bring about bioaccumulation or toxicity[13], which are criteria to be considered "substances of very high concern" (SVHC)

[8] Yuxin Wang et al. "Association of Serum Levels of Perfluoroalkyl Substances with Gestational Diabetes Mellitus and Postpartum Blood Glucose," *Journal of Environmental Sciences-China* 69 (July 1, 2018): 5–11, https://doi.org/10.1016/j.jes.2018.03.016.

[9] Suzanne E. Fenton et al. "Per- and Polyfluoroalkyl Substance Toxicity and Human Health Review: Current State of Knowledge and Strategies for Informing Future Research," *Environmental Toxicology and Chemistry* 40, no. 3 (December 7, 2020): 606–30, https://doi.org/10.1002/etc.4890.

[10] Fenton et al. (n 9) 616.

[11] ibid.

[12] Henry et al. (n 2) 328.

[13] Henry et al. (n 2) 329.

under the European Union's REACH regulation. The study concludes such characteristics differentiate fluoropolymers from other PFAS and may be regulated differently[14].

On the other hand, a 2020 Lohmann and colleagues found that there isn't scientific rationale in existing evidence to conclude that fluoropolymers are of low concern for environmental and human health due to their high persistence; emissions associated with their production, use, and disposal; and a high likelihood for human exposure to PFAS[15].

The enumeration of these limitations and conflicting points of evidence on the toxicological effects of exposure to fluoropolymers is to emphasize that the difficulty to specify why some effects are associated with exposure to PFAS does not warrant adding the entire class of PFAS chemicals to the list as EPA "toxic." Further research and risk assessments must be conducted before adding these chemicals to the list.

III. Policy recommendations and conclusions

The CHFCA understands that adding these substances to the list will not restrict the use of PFAS. However, as indicated earlier, we hope this proposed action will not set a precedent for a potential outright ban of PFAS in the future, before commercially viable alternatives enter the market. We hope that ECC continues its consultations with industry and, in these consultations, provide clarity on the goals and assessment process of adding PFAS chemicals to the list. For example, the CHFCA understands that the “State of PFAS” report will inform eventual policies to regulate PFAS. However, greater clarification is needed on what would entail the regulation of PFAS.

PFAS have unique opportunities to contribute to manufacturing hydrogen technologies that can help develop Canada’s 21st Century economy and realize the vision of a net-zero Canada. Therefore, **CHFCA recommends that ECC does not conclude that PFAS as a class should be added to the list of toxic substances in Schedule 1.** Instead, the CHFCA proposes the following:

- With an acknowledgment of the diversity of this class of chemicals, assess the risks of smaller related groups of PFAS and then use the information from this assessment to exempt from regulation the substances that do not meet the conditions to be classified as EPA “toxic”. The assessment of smaller groups would ensure a nuanced understanding of the health and safety risks of different PFAS exposure and, ultimately, a more precise classification.

[14] ibid.

[15] Rainer Lohmann et al. “Are Fluoropolymers Really of Low Concern for Human and Environmental Health and Separate from Other PFAS?”, *Environmental Science & Technology* 54, no. 20 (October 12, 2020): 12820–28, https://doi.org/10.1021/acs.est.0c03244.

- Continue to collect data using Chemical Management Plan information-gathering systems in concert with risk assessments to identify high priorities for appropriately justified risk assessment and management of PFAS chemicals. As toxicological effects associated with PFAS exposure are difficult to specify, greater collaboration between ECC and research organizations, such as the National Research Council of Canada, is needed to expand areas of research from not only the study of the effects of exposure to legacy PFAS, but also non-legacy "short-chain" PFAS and address other research limitations to ensure a greater understanding of the impacts from the exposure to fluoropolymers, for example, and to ultimately help ECC in formulating its proposal and regulation accordingly.

- Develop a framework to incentivize:
    a) Best practices for the manufacturing, use and end-of-life stages of fluoropolymers, implementing circular economy practices across value chains (closed circle with take-back system implementation and recycling/reuse at disposal stage) in the short and medium term,
    b) Procurement practices that reward products and technologies that use PFAS-free components, and
    c) The research and development of commercially viable non-fluoropolymers alternatives to PFAS (considering quality, durability, efficiency) and electrochemical energy recycling and re-manufacturing processes for hydrogen and fuel-cell technologies using policy mechanisms, e.g., funding schemes and the creation of taskforces.

- Provide the industry with a clear timeline on the regulation of polymers which might contain, for example, a breakdown of the plans to regulate PFAS with poor environmental fates pending the proving-out of alternatives.

Thank you for the opportunity to provide feedback on the *draft State of PFAS Report*. I would be pleased to discuss this further with you or your colleagues. I can be reached at 416-889 9804 or iveraperez@chfca.ca.

Yours truly,

Ivette Vera-Perez

Ivette Vera-Perez
President and CEO, CHFCA