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Management of PFAS with the Aid of Chemical Product Registries—An Indispensable Tool for Future Control of Hazardous Substances

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ABSTRACT

The Nordic countries are in the forefront of international chemical regulation and management by actively developing the domestic policy framework, while simultaneously pushing for more stringent control internationally. Norway, Sweden, and Denmark have been particularly progressive in the regulation of the per- and polyfluoroalkyl substances (PFAS). Restriction proposals have been developed under the EU Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and PFAS have been nominated for global restriction under the Stockholm Convention. A key tool in their work has been the product registries (PRs), where all chemicals imported and produced over a certain reporting limit must be registered by the importers and/or producers. In recent years these PRs have been facing opposition, predominantly from the industry. Simultaneously, and in some contrast, several EU countries are mobilizing for measures to control PFAS as a group. We explored the role of PRs in national and international chemical management. By analyzing the Norwegian PFAS data (2009–2017) reported by industry to the government we observed changes in use and temporal trends. A diversification in use and substitutions to alternative PFAS emerged when new policies were developed, representing a challenge for future control and reduction efforts. Instead of loosening up on reporting obligations, as advocated by some industry representatives, our analysis of the PFAS group argues that governments would benefit from a tighter reporting scheme of problematic compound groups. A comprehensive overview of use, production, and import would contribute to more effective control, thereby saving society and the environment from serious damage and tremendous costs. The Nordic PRs will continue to be important supplements to REACH registration and an indispensable tool for future both national and international regulation on PFAS and other hazardous substances. *Integr Environ Assess Manag* 2021;00:1–17. © 2020 The Authors. *Integrated Environmental Assessment and Management* published by Wiley Periodicals LLC on behalf of Society of Environmental Toxicology & Chemistry (SETAC)

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INTRODUCTION

Per- and polyfluoroalkyl substances (PFAS)

Perfluorinated substances such as perfluorooctanesulfonic acid (PFOS), perfluorooctanoic acid (PFOA), and perfluorohexane sulfonic acid (PFHxS) have become a global threat to human health and the environment. Almost all people in industrial countries have PFAS in their bodies today. The impact of PFAS on human health is tremendous in economic terms. In the European Economic Area the health impact has been estimated to cost between €52 and €84 billion per year according to Goldenman et al. (2019a). In the same report a summary of non-health-related costs for the next 20 years has been estimated to range between €170 and €821 billion. For Norway, aggregate costs covering environmental screening, monitoring, water treatment, soil remediation, and health assessment for the group of PFAS alone has an estimated cost of €194 million (lower bound 9 million and upper bound 2.2 billion) over the next 20 years (Dweik et al. 2012; Lin et al. 2017). In a recent publication (Cousins et al. 2020), an overview of strategies that could be used to inform actions for PFAS to protect human and environmental health has been reviewed.

PFAS regulation

Only a handful of PFAS have so far been regulated globally, whereas more have been regulated under Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), the EU regulation on chemical substances: PFOS, PFOA, and

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C9 to C14 perfluorinated carboxylic acids (PFCAs). A few more PFAS are identified as substances of concern by REACH.

The Nordic countries have been strong promoters of more stringent control of hazardous substances within the PFAS family. In 2005 Sweden proposed a ban on PFOS under the Stockholm Convention. The restriction was strongly supported by the Nordic countries. A few years later, the EU proposed listing of PFOA, again firmly supported by the Nordic countries, and a ban was adopted in 2019 and entered into force in July 2020. More recently, Norway proposed listing of PFHxS and related substances under the Stockholm Convention, a proposal that is currently under consideration. Hence the Nordic countries have been pivotal in shaping the few global regulations on PFAS that currently exist.

Within the EU there has been a strong drive for regulating several PFAS. Building on an initiative from Norway and Germany, PFOA was added to the list of Substances of Very High Concern (SVHC) in the EU's REACH Regulation in 2017, and Norway has registered an intention to submit a restriction proposal for PFHxS under the same body. Taking a more progressive stance on PFAS, Sweden and Germany made a joint proposal in 2018 to ban 6 PFAS, the longer chain PFCAs (C9–14), and other compounds that may degrade into 1 of the 6 compounds, in practice counting around 200 substances. The move was seen as an attempt to address a concern among both scientists and regulators worldwide that restricted or banned compounds are being substituted by structurally similar alternatives also possessing the same problematic properties (Enander 2016; KEMI—Swedish Chemicals Agency 2016; Nordic Council of Ministers 2018). Among the most proactive European countries, such as Denmark, Norway, and Sweden, it has been a more common trajectory to propose and establish a regional regulation with the EU first, and subsequently use that knowledge basis and experience to propose listing under the Stockholm Convention. Denmark and Sweden mainly work through the EU to regulate persistent organic pollutants (POPs) under the Stockholm Convention. Sweden nominated 1 of the first compounds after the Convention had entered into force; however, since then they have only worked through the EU system. Perfluorobutanesulfonic acid (PFBS) was recently added to the EU's candidate list of substances of very high concern after a Norwegian proposal. These initiatives have now materialized in the new EU strategy to phase out all non-essential use of PFAS (European Commission 2020).

The Nordic countries pushing the agenda

The Nordic countries are not only advocating more stringent control at an international level; they are also expanding national legislation when judging it necessary—particularly in those cases where the EU seems to be working at a slower pace or the internal coordination has proven cumbersome. A recent example was the proposal by Danish authorities to ban PFAS in food contact materials (Ministry of Environment and Food of Denmark 2019). Building on the updated risk assessment of PFOS and PFOA in food made by the European Food Safety Authority (EFSA), in combination with applying the precautionary principle on other PFAS, it was suggested to implement a ban while waiting for further action within the EU (Ministry of Environment and Food of Denmark 2019). Another example, which will be further elaborated in the present paper, is the recent decision by the Swedish government to strengthen the reporting obligation on PFAS, going far beyond the reporting requirements under REACH (KEMI—Swedish Chemicals Agency 2018b). In 2015 Sweden even sued and won over the EU Commission for moving too slowly on determining a definition of hormone-affecting chemicals (endocrine disruptors)—a group that likely includes several PFAS—so that these chemicals could be identified and further controlled. Sometimes, however, these national regulatory initiatives have been challenged. In 2013, Norway introduced a national ban on PFOA and was later indicted by the European Free Trade Association Surveillance Authority (ESA) for being in breach of harmonization requirements under REACH. However, the European free trade association (EFTA) court judged in Norway's favor. In recent years, ever more voices have criticized the current practice of regulating substance by substance. In December 2019 the Environment Ministers of Denmark, Luxemburg, Norway, and Sweden issued a letter to the EU Commission urging the EU to manage PFAS as a group (Norwegian Government 2019), calling for a ban on all PFAS, except those needed for what was termed "essential use" (Cousins et al. 2019). In May the following year, Germany, the Netherlands, Norway, Sweden, and Denmark agreed to prepare a joint REACH restriction proposal on "a wide range of PFAS" (ECHA 2020a). On 14 October 2020 the EU Commission adopted a new chemical strategy set to "phasing out the use of per- and polyfluoroalkyl substances (PFAS) in the EU, unless their use is essential" (European Commission 2020).

The product registries (PRs): A Nordic toolkit

The vast literature on the science–policy interface predominantly addresses the role and translation of scientific information. However, to develop policies on hazardous substances, industry data on use and volumes are essential supplements to scientific knowledge on transport, fate, and effect. In their progressive work on hazardous substances, the Nordic countries apply a rather unique management tool to support monitoring, management, and regulation of chemicals within their borders. The national PRs provide an up-to-date overview of hazardous chemicals that are manufactured, transferred, or imported in their countries. In addition, they have collectively set up a common Nordic database—the Substances in Products in the Nordic Countries (SPIN) database—where part of the PR data is submitted for a common overview of use and import (Product registries in Nordic countries). An important difference between PR and SPIN is that amounts lower than 100 kg are omitted from SPIN. Further, some data in SPIN are not available for reasons of confidentiality (e.g., if the substance is a component in fewer than 4 preparations from fewer than 3 producers). The PR data therefore are a more complete dataset, not limited by confidentiality regarding the amounts used.

Since 1981 Norway has had an official register of chemicals imported and produced in Norway. According to Norwegian legislation, manufacturers or importers who produce and/or place on the market 100 kg/y or more of a chemical classified as hazardous are obliged to submit a declaration to the PR. The hazard classification applied for the registry is based on the EU chemical labeling regulation, the Classification, Labelling and Packaging (CLP) (Regulation (EC) Nr 1272/2008). Although not a member of the EU, Norway has through its membership in the European Economic Area (EEA) harmonized and implemented the CLP and REACH regulation. The purpose of the labeling of substances through the CLP system that are potential hazards to health and environment is to ensure a high level of protection of health and the environment, and to facilitate free movement of substances and mixtures. The Norwegian PR will be used as a case study in the present work.

In recent years the Nordic PRs have faced opposition, mainly from the industry, arguing that the reporting requirements in the Scandinavian countries are redundant with the reporting requirements under REACH. Moreover, building on some of the same argumentation, even parts of the government have raised the question as to whether the PR has the right to exist. In Norway, the Ministry of Climate and Environment a few years ago raised its concerns and commenced a comprehensive evaluation of a potential closure of the registry. However, in contrast to these voices, the challenges posed by a particular arduous group of chemicals such as the PFAS may on the other hand challenge alleviation of existing reporting schemes and obligations. As stated by Wang et al. (2017): "As a first step toward understanding the global landscape of PFAS, it may be sensible to establish an inventory of legacy and currently used PFAS, including data on their chemical identity, production and uses, potential exposure media, regulatory status, and alternatives."

Within this special context of progressive Nordic chemical governance, an accelerating scientific and regulatory development scene on PFAS, and opposing views on the necessity and usefulness of the PRs, we explore here the role and significance of industry data provided through the PR. The aim of this study is 2-fold: 1) to carry out a deep-dive into the Norwegian PR to identify the PFAS in chemicals used in Norway during 2009 to 2017, their amounts, product category, and time trends; and 2) to use the PFAS group as a case to assess the Norwegian PR's current and potential future applicability and relevance in managing and regulating problematic groups of chemicals, nationally and internationally.

MATERIALS AND METHODS

Introduction

For the present study we applied a mixed-method approach integrating qualitative and quantitative data to enhance the analysis and explanatory power of the role and relevance of PRs as a tool in regulation and management of PFAS in Norway and beyond. The qualitative analysis is predominantly based on document analysis of primary data, such as official documents, including public consultations and communication, accessed under the Freedom of Information Act, which regulates the right of access to documents held by public authorities and public undertakings. The analysis was supplemented with secondary data such as scientific reports, workshop proceedings, and white papers. In order to validate and triangulate data, consultations with government stakeholders were conducted. The quantitative assessment and methodologies are presented more thoroughly in the sections below.

Selection of PFAS

An extensive list of PFAS ($n = 4730$) has been developed by OECD (2018). The OECD list contains useful information about the PFAS, such as structure categorization, which PFAS are polymers, and potential precursor to perfluorinated alkylated acids (PFAA) in the environment/biota. Also, KEMI—Swedish Chemicals Agency (2015) has established a list of substances considered to be PFAS ($n = 2702$ substances with a Chemical Abstracts Service registry number or CASrn). Nevertheless, a total of 202 CASrn were listed by KEMI, but not OECD. These 202 substances do not contain a long perfluoro chain $-C_nF2_n-$ ($n \geq 3$) or $-C_nF2_nOC_mF2_m-$ (n and $m \geq 1$). However, these 202 substances were included in our data register study (see Supplemental Data Figure S1 for illustration). The structure of these substances indicates that they are short-chain PFAS. We will denote these KEMI PFAS. The PFAS that were used in Norway during the period investigated (77 individual CASrn, listed in Supplemental Data Table S1) were further categorized by their chemical structures according to OECD, or alternatively categorized as KEMI PFAS. The main structure categorization of OECD is used further in this study (Table 1), and a list of OECD structure categories that were registered in Norway can be found in Table S1. Also, information about which substances that were categorized as being a polymer by OECD are included in figures whenever possible.

Extraction of data from the PR

Norwegian PR data related to hazardous substances in roads and motorized transport have previously been published (Grung et al. 2017). A more elaborate description of data registered in Norwegian PR can be found there. The PR contains information about chemical substances, which products they were used in, as well as which enterprises use them. A chemical in this setting is defined as a liquid/mixture/powder containing 1 or more substances. For some PFAS, the product categories were not specified. In these cases, information about the enterprise that used them is given (this was the case for 18 tons [of a total 249 tons] during the period). The PR data during 2009 to 2017 were extracted and submitted to us from the Norwegian

Table 1. OECD main categories of per- and polyfluoroalkyl substances

OECD main category (when available)	OECD category name	OECD structure description
100	Perfluoroalkyl carbonyl compounds	$C_nF_{2n}+1$_C(O)_R
200	Perfluoroalkane sulfonyl compounds	$C_nF_{2n}+1$_S(O)(O)_R
300	Perfluoroalkyl phosphate compounds	$C_nF_{2n}+1$_P(O)_R
400	Fluorotelomer-related compounds	
500	Per- and polyfluoroalkyl ether-based compounds	$C_nF_{2n}+1$_O_$C_mF_{2m}+1$_R
600	Other PFAA precursors and related compounds—perfluoroalkyl	
700	Other PFAA precursors or related compounds—semifluorinated	
800	Fluoropolymers	

PFAA = perfluorinated alkylated acids.

Environmental Agency (NEA). Confidential information such as the registrant and product names was not part of the shared data.

There is no production of PFAS in Norway; therefore all domestic releases of PFAS to the environment are a result of an article or chemical containing PFAS being released. Articles are not reported to the PR and are therefore not included in our data. Our definition of an article is a solid material such as textile, car, or paper that is imported or produced, and used as is by the consumer. Many PFAS-containing articles are imported to Norway, including impregnated textiles, carpets, and household apparel. Also, PFAS as additives in cosmetics, personal care products, and pharmaceuticals add to the environmental burden. Under the current reporting regime, it is difficult to know how much PFAS articles contain without analyzing them, because neither articles nor cosmetics, personal care products, etcetera, are reported to the PR.

Treatment of data

The data from PR were added to an Access database. To the database, a list of CASrn of PFAS (Supplemental Data Figure S1) was added. A query based on CASrn in the PR data and the PFAS list gave a dataset of PFAS used in chemicals in Norway during 2009 to 2017. This dataset is presented in the following section.

Data were further processed and visualized using JMP (v. 15.2.0; SAS Institute). JMP was also used for statistical treatment of data such as ANOVA, multivariate statistics (principal component analysis [PCA] and multiple correspondence analysis [MCA]), and linear regression (all statistical treatments are illustrated in figures in the Supplemental Data).

RESULTS AND DISCUSSION

In the first part of this section we present the analysis of the PFAS data registered with the PR between 2009 and 2017. We examined the volumes used, the type of use, and temporal trends. The latter will reflect shifting trends in structure categories, product categories, chain lengths, and chemical categories. These are considered key elements in understanding the use, import, and potential exposure of PFAS nationally, and for developing targeted and efficient control policies. Drawing on this analysis we discuss relevant shifts in use and the role of the PR in PFAS management, nationally as well as internationally. In the latter part we also assess to what extent the PR is overlapping with REACH registration requirements, we ask whether the PFAS chemicals may be slipping under the authorities' radar, and evaluate the arguments for and against national PRs. Combined, this information will shed light on the potential relevance of PRs in chemical management.

PFAS use during 2009 to 2017

A total of 77 PFAS CASrn were registered in at least 1 of the years during 2009 to 2017 (see Supplemental Data Table S2 for details). The different PFAS were classified according to the OECD structure categories (Table 1) or denoted as KEMI PFAS. The structure categories containing most CASrn were OECD main category 400 (fluorotelomer-related compounds) ($n = 38$, 49%), 200 (perfluoralkane sulfonyl compounds) ($n = 15$, 19%), and 800 (fluoropolymers) ($n = 7$, 9%) (Supplemental Data Figure S1).

The total tonnage of PFAS during the 9-year period investigated was 249 tons. The amounts for all CASrn including OECD structure category are listed in Supplemental Data Table S2 and are depicted in a treemap (Figure 1). Fluorotelomer-related PFAS (OECD category 400) was the group with highest tonnage (152 tons), followed by fluoropolymers (OECD category 800) (51 tons). The amount of KEMI PFAS was substantial, with 26 tons. During the period, the use of OECD categories 400, 800, and KEMI PFAS (short fluoro chains) accounted for 61%, 21%, and 11%, respectively, of the total use. Also precursors to PFAA were used, divided into 2 different groups according to OECD (2018), either precursors to PFAA (perfluoroalkyl acids)—perfluoralkyl ones (OECD category 600) or other precursors to PFAA semifluorinated ones (OECD category 700). OECD

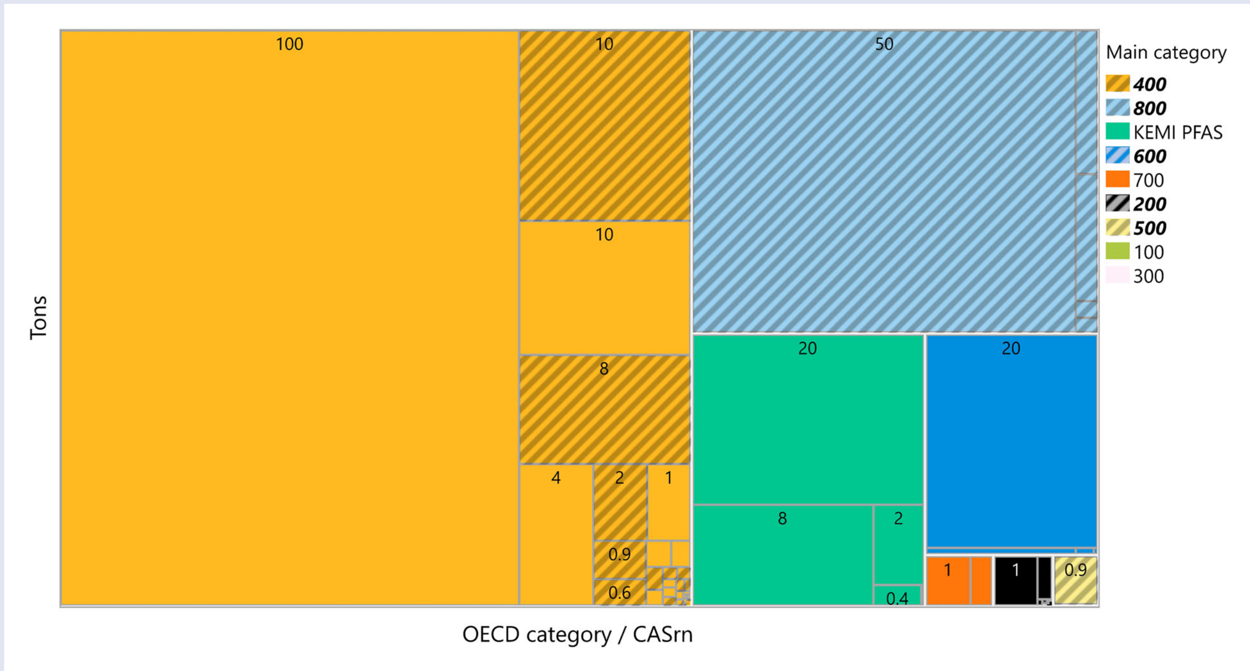

Figure 1. Treemap of amount (tons) of per- and polyfluoroalkyl substances (PFAS) imported to Norway during 2009 to 2017. The total area represents 249 tons, and the squares are proportionate to amounts used. The squares are colored according to PFAS structure category according to OECD or denoted KEMI PFAS. The shaded Chemical Abstracts Service registry numbers (CASrn) are listed as polymeric by OECD.

categories 600 and 700 were used in a total of 17 tons during the years studied.

A mean of almost 28 tons of PFAS in chemicals were imported annually over the 9-y period. A few PFAS represented the main types of use; 19 PFAS (Table 1, Supplemental Data Figure S3) used in more than 500 kg represented 99% (246 tons) of the total tonnage. For these 19 PFAS, a description of structure (where known), information of use in products, and toxicity data are given in the text in the Supplemental Data.

In what type of products were the PFAS used?

Information of which kinds of products contain PFAS and which enterprises use the products are registered in the PR. The products that contained PFAS were therefore studied more closely and are portrayed in Figure 2. Only products that contained more than 200 kg PFAS were included. This amounted to 248 tons of PFAS, which are included in Figure 2 (>99% of PFAS).

Products for firefighting purposes were the largest product category, with 57% of the PFAS tonnage used during the period investigated. Otherwise, the use in products was quite diverse, with large amounts of PFAS being used in paint and varnish, as surface-active agents, products for reduction of friction, etcetera. A total of 20 product categories contained more than 200 kg of PFAS during the period. A few of the applications did not specify the product category, and then the enterprise utilizing the product has been given (e.g., industrial use and oil production).

Combining the information about structure category of PFAS with product category gave useful information and is depicted in Figure 3. The different product categories are linked to different categories of PFAS. The main uses of OECD category 400 PFAS were firefighting foams, paper impregnation agents, other impregnating agents, and construction filling materials. In addition, firefighting products contained OECD category 600 PFAS. KEMI PFAS were mainly used in surface-active ingredients, cooling agents, explosives, and filling materials. Fluoropolymers (OECD category 800) were used in a variety of products, where the main uses were in paint and varnish, friction-reducing additives, explosives, and lubricants. Paint and enamel contained OECD category 200 PFAS during the period, and in addition fuels also contained OECD category 200 PFAS. OECD category 700 PFAS were used as cleaning agents (production of video, film, and TV) (see description of CASrn 163702-06-5 in the Supplemental Data). Degreasers contained OECD category 500 PFAS (per- and polyfluoroalkyl ether-based compounds), and there was also some industrial use of OECD category 500 PFAS. See also correspondence analysis of the results in the Supplemental Data (Figure S4).

Temporal trends

Structure category of PFAS. The data presented cover a 9-y period, allowing for an analysis of temporal trends as shown in Figure 4. The yearly import was almost 28 tons yearly during the period, with lower amounts in 2013 and 2014 indicated by

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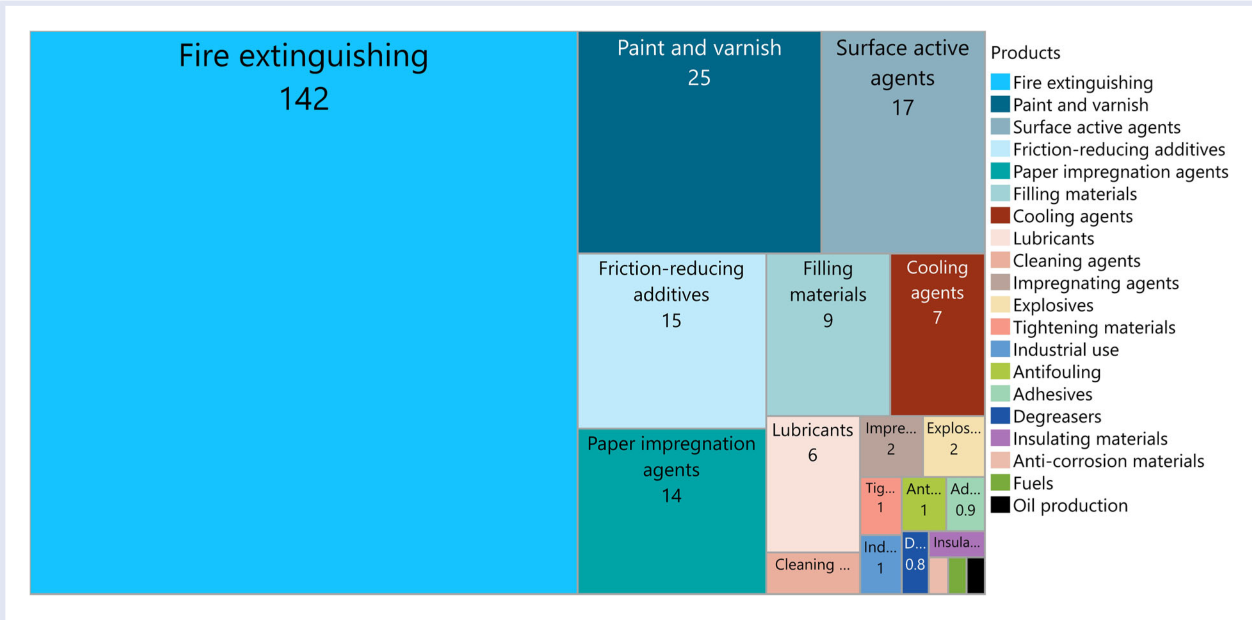

Figure 2. Treemap of use of per- and polyfluoroalkyl substances (PFAS) (in tons) during the years 2009 to 2017 categorized by use. Only product categories with >200 kg PFAS used are included. The total area represents 248 tons.

narrower columns for these 2 years (Figure 4). The use of fluorotelomer-related PFAS (OECD category 400) declined from an average of >80% early in the period to about 25% in 2017. The use of PFAS was more diverse with respect to OECD category later in the period, with increased use of fluoropolymers (OECD category 800), KEMI PFAS, and OECD category 600 (other PFAA precursors and related compounds—perfluoroalkyl ones). The use of perfluoralkane sulfonyl PFAS (OECD category 200) was low in the period and occurred mainly during 2014 to 2016. The temporal data for structure category PFAS were analyzed using PCA; see Figures S5 and S6 and text in Supplemental Data).

Product categories utilizing PFAS. The temporal trend of product categories using PFAS is depicted in Figure 5. The same pattern as observed in Figure 4 is visible, especially for the yellow cells (OECD category 400 PFAS in Figure 4 and fire extinguishers in Figure 5) and are expected since OECD category 400 PFAS were used as fire-extinguishing products (Figure 3). Norwegian airports and most oil installations have

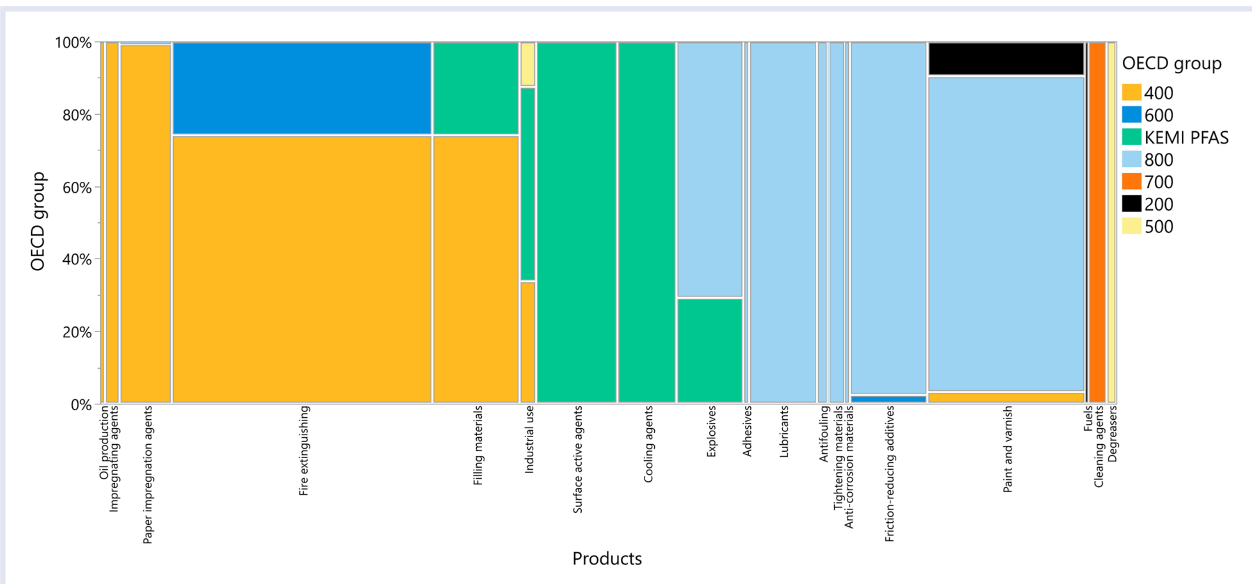

Figure 3. Mosaic plot of product categories versus OECD structure categories of per- and polyfluoroalkyl substances (PFAS) used in the products. Only product categories with amounts >200 kg/y are included; the total amount of PFAS included in the figure represent 248 tons. The amount (tons) was used to weigh the data but were transformed (logx + 1) to allow visibility of product categories. The same color scheme as in Figure 1 is employed for different structure categories of PFAS.

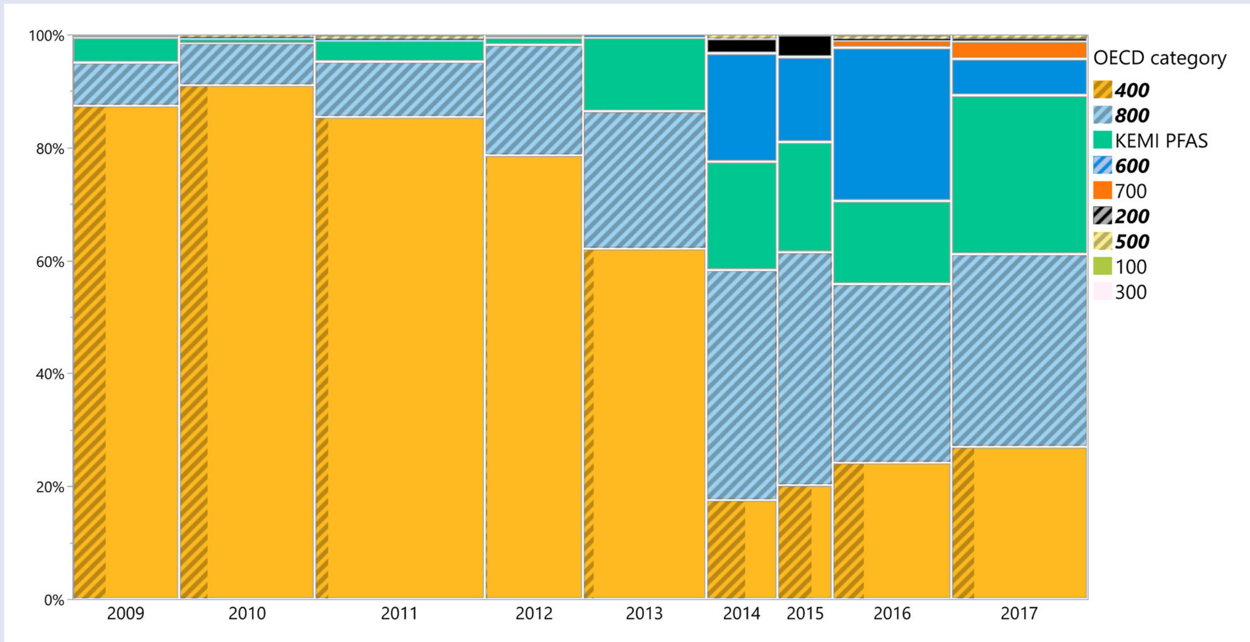

Figure 4. Mosaic plot of temporal trends of structure categories of per- and polyfluoroalkyl substances (PFAS) in Norway. The total area represents 249 tons of PFAS. The colors for different structure categories of PFAS are the same as in Figures 1 and 3, and the shaded areas represent PFAS that are listed as polymeric by OECD.

since 2011 replaced fluorinated firefighting foams with fluorine-free alternatives, and this reduction is probably the reason behind the reduction observed for fire-extinguishing products in Figure 5. PFAS used in paper impregnation agents (presumably food contact materials) were used up to 2011 but have since been stopped. Also, use of PFAS in impregnating agents has been stopped. Use of PFAS in paint and varnish was constant in the period. However, starting in 2012 several new product categories started using PFAS: surface active ingredients, friction reduction products, filling materials, lubricants, and cleaning agents. PFAS as cooling agents have been used during all the years but increased from 2015 and later. Use of PFAS in explosives occurred only in 2013 and 2014.

PFAS are virtually nondegradable, and well-investigated compounds like PFOS and PFOA have been shown to

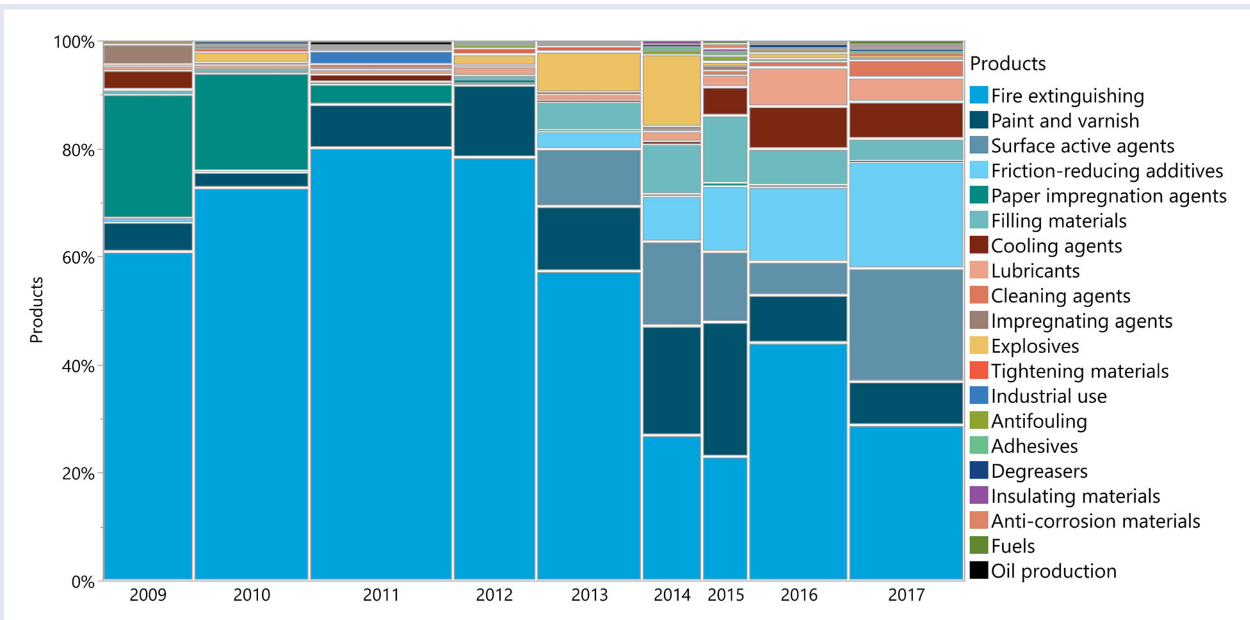

Figure 5. Mosaic plot of temporal trends of yearly ratio of product categories registered as containing per- and polyfluoroalkyl substances (PFAS) in Norway. The areas are weighted according to the tonnage used. The same color scheme as in Figure 2 is used. The total area represents 248 tons, and only product categories >200 kg are included.

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possess properties that make them hazardous. More and more PFAS are being regulated because of their extreme persistence and toxic effects, although the restricted substances continue to represent a minor fraction of the roughly 5000 substances within the group. Hence the trend that we observe in Norway is problematic. Since 2011 the application of PFAS has become increasingly more diverse. Most of the product categories reported here fall into the nonessential product categories as described in Cousins et al. (2019). Diversification and increasing nonessential use of PFAS is challenging for the management of hazardous substances because it may make it more difficult to regulate, manage, and control, and a significant share of PFAS may eventually be released to the environment.

Chain length of PFAS. OECD has gathered information about the chain length of PFAS, and the temporal trend of chain lengths of PFAS is portrayed in Figure 6. The PFAS that are registered as polymers by OECD are shaded (total 77 tons). The fluoropolymers have a perfluorinated backbone; several other PFAS include polymers where the polymeric backbone is not perfluorinated, while side chains are perfluorinated with different lengths of the perfluorinated side chains, which are then shaded in Figure 6. The use of chain length 6 was the largest group during the period (46%), followed by fluoropolymers (20%), PFAS with no information on chain length, and KEMI PFAS (12% and 11%, respectively). During the period, there was a reduction in use of chain length 6, whereas chain lengths of 3, 4, and 8 increased. Also, the use of fluoropolymers and KEMI PFAS increased. The increased use of chain length 8 since 2013 is problematic since the likely degradation products are PFOS and/or PFOA. The use of chain length 6 PFAS was reduced to 0.52 tons in 2014 but subsequently increased and reached 4.1 tons in 2017. PFAS with shorter chain lengths than 8 are not as extensively studied as PFOS and PFOA, but the half-life in human blood for PFHxS is even longer than PFOS and PFOA. Also, the shorter chain PFAS are now recognized as hazardous substances, and PFBS was recently identified as an SVHC in the EU.

Use of PFAS by nonprofessionals (private use). Information about private use of compounds is to a certain degree available in the dataset. By and large, this category represents volumes used by private consumers and is registered in the PR as an enterprise termed "private use." We extracted all data in the material that were classified as being used privately. This totaled 3.4 tons during the period (1.4% of total use). The temporal trends of different structure categories of PFAS are shown in Supplemental Data Figure S7. The use of OECD category 400 is high early in the period, with a marked decrease after 2013. However, the striking difference between private use and total use is the marked increase of OECD category 200 PFAS, which started in 2014, amounting to a total of 780 kg. In total, 6 different CASrn of OECD category 200 were used, but 2 CASrn (76752-82-4 and 67906-42-7) had the highest use in paint and varnish and as fuels (480 kg and 290 kg, respectively). The Norwegian Environment Agency informed that the latter product is a fire starter for wood combustion in fireplaces in private homes. The other product categories were impregnating agents and cleaning agents.

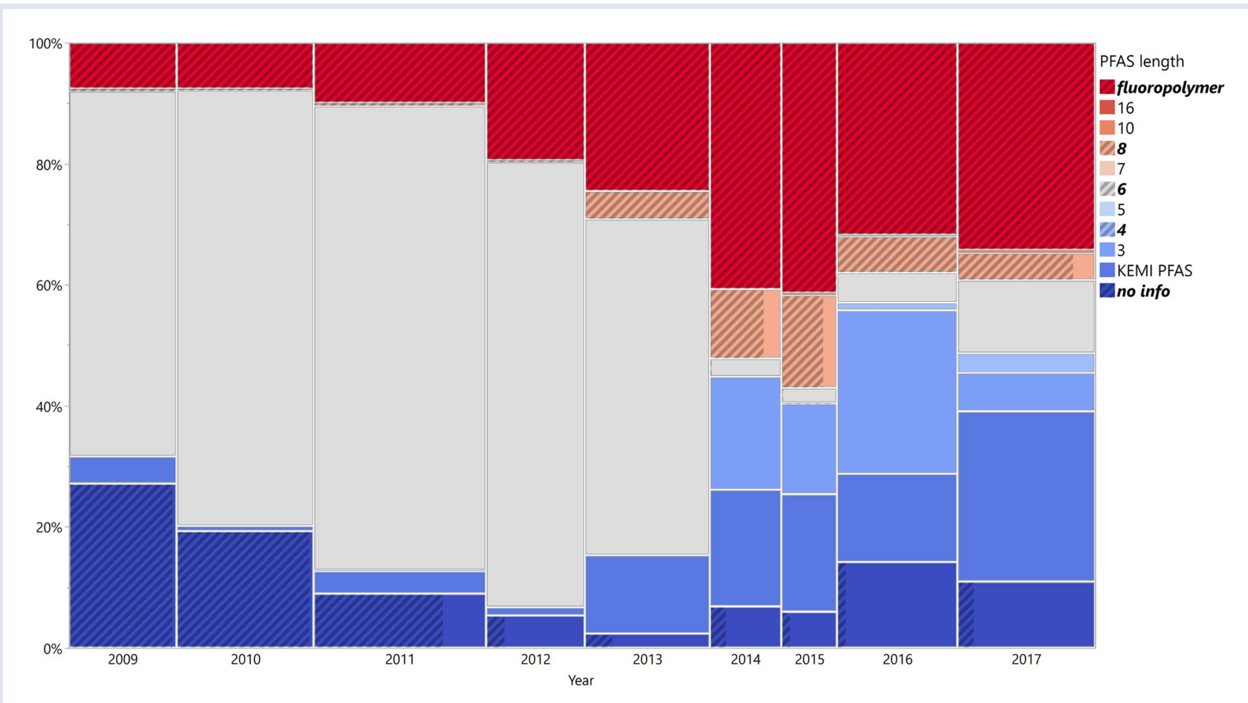

Figure 6. Temporal trend of length of per- and polyfluoroalkyl substances (PFAS) used in Norway. The total area represents 249 tons. "No info" means that OECD gave no information about chain length. KEMI PFAS are shorter chain lengths (1–2). The shaded areas represent PFAS listed as polymers by OECD.

PR data reveal changes in use

The present in-depth study of the chemicals registered in the Norwegian PR reveals several features and trends that are relevant for improving future chemical management and control:

- PFAS below 100 kg and PFAS not registered under CLP are not registered in the PR, unless being a constituent of a mixture where any of the other chemical substituents meet that criterion.
- A wide range of nonregulated PFAS are imported and used in Norway, of which some are likely to be hazardous and have been regulated elsewhere (e.g., CASrn 220459-70-1—banned in Canada).
- Precursors to PFAA, likely to degrade into already banned/regulated substances, were among the high-volume chemicals registered (CASrns 756-13-8 and 163702-06-5).
- There has been a significant shift in use between 2009 and 2017: 1) As from 2011, the use of PFAS has become far more heterogenic, including a wide range of purposes. This is highly relevant knowledge for the development of appropriate policy action, as such a trend may make it more challenging to mitigate and control release and exposure. 2) As regulations/bans are announced, the market appears to shift to other PFAS, for example, the increasing use of shorter fluorinated chains disclosed in the present analysis.
- Fluoropolymers represented 21% of the registrations in volume (51 tons), while polymeric sidechain PFAS (nonperfluorinated backbone) represented 26 tons (10%). Polymers are not required to be registered under REACH; however, they will be registered under the Norwegian PR if the compound or any of the mixture constituents have a quantity of >100 kg and are labeled under the CLP.
- Some registrations may come with errors or be based on low-quality data, thus introducing certain weaknesses and challenges when interpreting the data. This was the case for 2 registrations of PTFE (222 and 413 tons in 2016)—outliers that we could not verify as valid data points.

The tendency for industry to replace regulated, or soon to be regulated, chemicals with similar chemicals, possessing much of the same inherent and hazardous characteristics, calls for close attention by governments and scientists to monitor those shifts (KEMI—Swedish Chemicals Agency 2015; Nordic Council of Ministers 2018). However, in order to keep track of chemical product development and market dynamics the PR must be used actively and monitored closely, to detect potential precursors, emerging PFAS substances, and changes in product categories or uses. It may be expected that it is more cost efficient and sounder to monitor such changes in production and import, rather than trying to detect the "needle in a haystack" through detecting such changes in the environment through environmental monitoring. An active use of the PR, studying substances and use, may also contribute to illuminating the potential of fluorinated compounds leaking from polymers. Moreover, it is a suitable tool for prioritizing and detecting new potential candidates for the environmental screening program of emerging chemicals carried out by the environmental authorities. The siloxane (CAS nr. 69430-43-9) detected in the present study is an example of a chemical that is worth paying closer attention to, since several other (cyclic) siloxanes have been found in high concentrations in Norwegian freshwater fish and some of which have been regulated within the EU (Borgå et al. 2012, 2013).

Only a part of the picture. The data presented here represent only a fraction of the PFAS chemicals used in Norway. The background for such a limitation is that most PFAS are not registered in the PR because only a few PFAS are classified under the CLP and therefore trigger registration under the PR. Even persistent bioaccumulative and toxic (PBT) and very persistent and very bioaccumulative (vPvB) substances do not trigger CLP classification, since these are covered by the REACH regulation. Of the 72 OECD-listed PFAS in the present study, only half (38) were preregistered in REACH, and 7 were registered. Hence many of the PFAS reported here are registered because *other* chemicals in the product are classified under the CLP, and therefore all compounds in the product need to be registered. Lastly, and most importantly, any PFAS added to finished articles (textiles, house apparel, personal care products, etc.) that may leak into the environment during and after use (as waste) are not accounted for in the PR (Skjelvik 2010). In the following section, we will elaborate further on the role of the Norwegian PR in management and regulation of hazardous chemicals, including its limitations and potential improvements.

Regulation and management of PFAS: The role of product registers

The following section will describe the important characteristics of the Nordic PRs, essential differences between them and the potential for overlap with the REACH chemical registration system. Taking a closer look at the Norwegian PR we explore the uses of the PR and its role in chemical management—nationally as well as internationally. We discuss whether some of the more problematic chemical groups, such as PFAS, warrant a different registration regime. Moreover, we describe some of the different perspectives on the use of PRs in Europe today. Lastly, we draw on the lessons learned from the data analysis presented above to conclude on the role and relevance of the PR in managing and regulating PFAS in particular.

The Norwegian product registry versus REACH. Most EU countries do not have a PR like the Nordic countries as it is not an EU requirement. Even though both the Nordic PRs and REACH require manufacturers and importers to register substances when they are placed on the market, there are key differences between the registration systems (Table 2). Whereas the Nordic PRs contains information about all hazard

Table 2. PFAS with a consumption of ≥500 kg in any of the years 2009 to 2017 ($n = 19$). The table is sorted according to total amounts (in tons). The tonnage (each year) has been given with 2-digit precision (3 for summary column for tonnage >10 tons). Negative numbers signify export (out of Norway), while empty cells signify that the amount was zero

CASrn	PFAS list	Molecular formula	OECD detailed structure category	Perfluoro-alkyl chain length	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total (tons)
80475-32-7	OECD	C13 H17 F13 N2 O3 S	402.08	6	16	24	32	18	17	0.019		1.5	2.0	110
9002-84-0	OECD	(C2 F4)*x*	801	>20	2.0	1.9	3.0	4.4	5.7	5.3	5.6	9.1	11	48.6
69430-43-9	KEMI	Unsp.[a]							3.3	2.7	1.8	1.8	7.1	**16.7**
756-13-8	OECD	C6 F12 O	608	3						3.3	2.1	8.1	2.2	**15.6**
220459-70-1	OECD	Unsp.	403		6.1	6.1	1.5							**13.7**
161278-39-3	OECD	(C F2)*n* C9 H19 F N2 O4 S	402.08			0.00017	0.22	0.80	0.11	0.70	0.65	3.9	3.2	**9.6**
160336-09-4	OECD	Unsp.[a]	403.01	8	0.11	0.063	0.14	0.020	1.4	1.5	1.6	1.8	1.3	**7.9**
354-33-6	KEMI	C2 H F5			0.96		1.3			0.072	0.72	2.3	2.3	**7.7**
34455-29-3	OECD	C15 H19 F13 N2 O4 S	402.08	6	0.059	0.18	1.2	0.33	0.19	0.50	0.34	–0.56	2.2	**4.4**
70969-47-0	OECD	(C3 H5 N O)x. Unsp.	402.12		0.063	0.10	0.85	0.23	0.13	0.13	0.058	0.017	0.13	**1.7**
406-58-6	KEMI	C4 H5 F5			0.20	0.19	0.34	0.15	0.25	0.14	0.14	0.15	0.14	**1.7**
68187-47-3	OECD	Unsp.[a]	402.12		0.077	0.10	0.51	0.19	0.27	0.12	0.024	0.019	0.060	**1.4**
9011-17-0	OECD	(C3 F6. C2 H2 F2)*x*	807		–0.030	0.58	–3.7	0.29	1.9	1.9	0.077	0.24	0.13	**1.3**
98728-78-0	OECD	(C6 H12 O2. C4 H8 O. C2 Cl F3)*x*	800				1.2							**1.2**
163702-06-5	OECD	C6 H5 F9 O	702.1	4								0.26	0.73	**0.99**
76752-82-4	OECD	C8 H2 F17 N O2 S. C6 H15 N	203.01	8						0.48	0.48			**0.96**
69991-67-9	OECD	Unsp.[a]	501.05		0.000030	0.13	0.31	0.00015	0.000095	0.097	0.00043	0.22	0.20	**0.94**
148878-17-5	OECD	Unsp.[a]	403.01		0.85									**0.85**
203743-03-7	OECD	Unsp.[a]	403.01		0.073	0.095	0.21		0.027	0.032	0.050	0.050	0.046	**0.59**
Total (tons)					**27**	**34**	**39**	**24**	**30**	**17**	**14**	**29**	**33**	**246**

[a] Unspecified molecular formula.
CASrn = Chemical Abstracts Service registry numbers; PFAS = per- and polyfluoroalkyl substances.

Table 3. Key differences between chemical registration within the Norwegian project registry (PR) and Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

Chemical information	Norwegian PR	REACH
Common		
Substance ID	Yes	Yes
Classification (CLP)	Yes	Yes
Area of use—substance	Yes	Yes
Quantity of substance	Yes (Norway)	Yes (EU)
Identity of manufacturer/ importer	Yes	Yes
Market	Norwegian	EU
Reporting on impurities	No	No
Articles and/or finished products	No	No
Difference		
Mixtures and/or preparations	Yes	No
Area of use—mixture and/or preparations	Yes	No
Quantity of mixture and/or preparations	Yes	No
Hazardous chemicals on private market	Yes	No
Registration of polymers	Yes, if CLP labeled and >100 kg	No
Registration criteria	Danger, labeling and volume	Only volume
Registration criteria volume	100 kg per annum	1000 kg per annum

classified chemical products—substances *and* mixtures—REACH only contains information about substances above a certain threshold volume. The Nordic PRs contain complete information about the substituents of the chemicals, available or produced on the domestic market, as well as the quantity and the area of use (Ahrens and Reihlen 2007; Ministry of Climate and Environment, Norway 2016). The Norwegian PR also includes hazardous chemicals used by private consumers, information about biocides, microbiological products, and chemicals used for explosives. In addition to the key differences illustrated in Table 3, REACH contains elaborated information about exposure, health effects, and environmental impacts that are not registered in the PRs.

Investigating differences between the Nordic PRs and REACH, the latter being in its infancy at the time of writing, Ahrens and Reihlen (2007) identified significant differences between the 2 systems when it comes to both purpose and content. According to the authors the overlap between the 2 was "limited to the identify of substances, the identity of manufacturer/importer, and the generic use of the substance as anticipated by the manufacturer" (Ahrens and Reihlen 2007). Since then, some differences have been modified or reduced, including the criteria for registering chemicals under REACH, that just recently, in 2018, was considerably lowered from 100 tons per annum to 1 ton.

The EU regulation requires that any supplier of chemical substances and preparations for professional use must accompany a safety data sheet (SDS) to its customer. The SDS is mainly used for professional health and safety matters, as it is not required to submit the SDS together with products for private consumers, provided that the chemicals are labeled with sufficient information (e.g., danger labels) to protect users sufficiently (NEA, https://www.environmentagency.no/areas-of-activity/product-register/declaration-of-chemicals/). Although the SDS also contains information about the chemical preparations, like the Norwegian PR, the information is not comprehensive. The SDS contains information about hazardous characteristics, areas of use, some of its content (ingredient substances), and appropriate measures for safe handling and storage of the substance/preparation (Table 2). However, the information about content is neither detailed nor exhaustive, as it predominantly contains information about the substances that trigger classification (harmonized and/or self-classified) in accordance with the CLP regulation and certain substances under REACH. The CLP Regulation (EC) Nr. 1272/2008 is based on the United Nations' Globally Harmonized System (GHS) and its purpose is to ensure a high level of protection of health and the environment, as well as the free movement of substances, mixtures, and articles. The SDS also comes with responsibilities for the downstream user, who must check whether the exposure scenario covers its conditions and take appropriate measures to control the risks. Hence it provides no information on volumes. Currently, the SDS are available only in PDF format and not in databases or a register. Hence it is poorly accessible through searches and is not facilitating reporting of the content of substances in mixtures.

The comparison reveals that the practical applicability is substantially different when comparing the Norwegian PR and the REACH registration system. More specifically, the PR is designed to compile the full chemical composition, area of use and product type, and quantity in 1 database, where data can be extracted for further examination by the government, researchers, or others. In contrast, it will be difficult to use the SDS and the REACH-registered information to investigate patterns and shifts in use and market volumes, and as key input data to monitor and ensure enforcement of REACH. The EU registration system does not include mixtures and/or preparations and will thus miss out a complete overview of the content of chemical preparations. Furthermore, although the registration requirement under REACH will include all individual substances, including those *without* a danger classification, the elevated cut-off registration limit of 1000 kg per annum implies that it will miss out information about potentially potent and hazardous chemicals present at lower but still in

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potentially relevant volumes for environmental and health impact (Nordic Council of Ministers 2018).

What about polymers? Polymers have commonly been used to replace other PFAS. Studying the occurrence and use of PFAS in 2015, mapping more than 3000 PFAS in use, the Swedish Chemicals Agency (SCA) identified polymers as the largest group of substances (KEMI—Swedish Chemicals Agency 2015). A substantial proportion of them did not have a CAS number. The report concluded that there was a lack of information on this group under REACH, since the concentrations of PFAS generally were below the elevated threshold for registration (1000 kg per annum). In fact, polymers do not have to be registered under REACH, unless it contains more than 2% of an unregistered monomer and/or substance and the quantity of such monomer and/or substance makes up more than 1000 kg per annum (ECHA 2020b). Hence it has been claimed that since the majority of PFAS currently on the market are polymers, a majority of PFAS are also excluded from REACH registration. The lack of registration requirement implies that there will be no restriction on the polymer and the importer or producer does not have to provide data on toxicity. Government officials have raised concerns that for some substances it is not clear whether they are defined as a polymer or not, based on the existing REACH definition (Nordic Council of Ministers 2018). There is an ongoing process under the EU to evaluate inclusion of registration requirement for polymers in the coming years (Nordic Council of Ministers 2018; Goldenman et al. 2019b). In a workshop on PFAS, with policymakers from the Nordic countries, Austria, and Germany, it was proposed to include registration of polymers under REACH (Nordic Council of Ministers 2018). Under Nordic PRs, registration of polymers will to a larger extent—but not entirely—be registered: in Sweden, provided it makes up 5% or more of the content; in Norway, *directly*, if it is CLP labeled and above 100 kg per annum, or *indirectly* (including any quantity below 100 kg), if it is part of a mixture where any other chemical constituent is CLP labeled and above 100 kg.

Impurities and articles. Since all the Norwegian PRs and REACH have a cut-off criterion for registration between 100 and 1000 kg, respectively, there is no obligation to report on *impurities* in products—not even when they are part of a high-volume mixture or may be degraded into a substance that is being imported or produced in a quantity above the limit. Interestingly, due to the Norwegian requirement to declare the complete (100%) composition of a mixture, including the relative share of each substance, the impurities may be indirectly reported when being part of a mixture that includes another chemical that falls under the CLP requirements and is above 100 kg per annum. The reporting of impurities will obviously also depend on the manufacturer and/or importer being aware and having detected and quantified the impurity. Impurities challenge authorities when assessing hazardous chemicals and their potential impact, as well as executing monitoring activities. The lack of knowledge on PFAS used by industry, the tendency towards a more heterogenic application of such substances, and a reluctance to share information on chemical composition (to be elaborated further below) may impose a high burden and cost on governments and society. Such information may then have to be sought retrospectively—for example, through monitoring activities, assessment of impacts, and remediation (Goldenman et al. 2019b).

Until now there has been no requirement under Norwegian law to register PFAS chemicals in *articles* (not intended to be released) that are imported. Both nonregulated and banned PFAS have been detected in various consumer products, with a potential for human exposure and environmental release (e.g., Herzke et al. 2012; Kotthoff et al. 2015; Ye et al. 2015). Such items may release hazardous chemicals, including potential precursors, during production and use and in waste management/disposal. The registration of substances in articles is also exempted under REACH. Thus, in the abovementioned policymaker workshop, 1 of the conclusions was to enable registration and authorization of substances also in articles (Nordic Council of Ministers 2018). Such registration would enhance traceability, monitoring, and control of release to the environment, including from diffuse sources. Moreover, it could contribute to reducing the risk of contamination of waste and recycling cycles. Such a registration scheme is now being rolled out under the EU Waste Framework Directive, which Norway also adheres to. As from 5 January 2021, suppliers, producers, and importers must register any SVHC in a concentration above 0.1% (w/w), in a database for information on Substances of Concern in articles as such or in complex objects (Products): the SCIP-database (ECHA 2020c). Although this will accommodate the lack of registering PFAS in articles, its scope is still restricted by the fact that only a handful of PFAS have so far been identified as an SVHC (ECHA 2020d).

Are the PFAS flying under the radar? In 2014, around 20 scientists encouraged the Swedish government to establish a commission to evaluate the explanation for and impacts of the ongoing releases of PFAS in firefighting foams (Enander 2016). In 2015, the Swedish government followed the advice and set up a commission to analyze and map the sources, the pollution status, the actors involved, information exchange, and possible mitigation measures. Some of the key messages and recommendations in the evaluation report concerned the registration of chemicals, including the following (Enander 2016):

- The reporting requirements to the EU and the (Swedish) PR are weak when it comes to substances in low concentrations in a mixture, where information on environmental and health risk is missing, and the total sales volume is low.
- Substances in small concentrations or volumes must also be included by the registration requirement.
- The content of chemical substances must be reported openly—for example, which type of PFAS—and made

publicly available (requires a change to the CLP REACH system).

- The registries do not contain sufficient information to carry out a macro-environmental or a trend analysis.
- The substitution requirement must cover groups of chemicals; it is too costly and cumbersome to do 1 by 1.
- The evaluation requirements for government prior to restrictions are demanding, considering the fact that it is the obligation of any producer, importer, or vendor to ensure that the chemicals being taken into use pose a risk to humans and the environment; thus the evaluation requirements for government must be reduced.

The report stated that under the current regime the declaration of the complete contents of a product is not required, the content of PFAS in products is often kept confidential by the industry, and any evaluation made by the producer is not publicly available. An improvement of the registration process was recommended to include also PFAS present at low concentrations. Several government reports and assessments on PFAS have reiterated such concerns and emphasized the specific issues associated with PFAS (KEMI—Swedish Chemicals Agency 2016, 2018a; Nordic Council of Ministers 2018):

- The potency and effective technical properties of PFAS imply that they are often used in very low concentrations, below both the EU (1 ton) and the Swedish threshold (100 kg).
- For each application, a low volume is often required; thus the tonnage used is commonly below the registration level used under REACH.
- As a consequence of avoiding registration, there is limited knowledge under the REACH system about how hazardous the chemicals are.
- The lack of knowledge on hazardousness for most PFAS under REACH will in consequence make it invisible in the product register, as the criteria for reporting to these registers is based on CLP-based hazard classification (a product containing the concentration of a single PFAS below 5% does not have to be reported, unless classified hazardous).

Considering the close similarity between the Norwegian and the Swedish PR, the critique raised would also encompass the former. One of the conclusions made in these reports was that neither the PR nor the REACH system could provide a complete picture on how PFAS are used in Sweden or elsewhere. Thus it was concluded that the legislative framework was not adequate for managing risk from PFAS (KEMI—Swedish Chemicals Agency 2016). Building on these assessments, the Swedish government thereafter started developing new reporting requirements specifically for PFAS. On 5 November 2018, the government announced that all companies that already report to the PR are, as from 1 January 2019, required to inform whether the product contains additionally added PFAS, *independent of the concentration* (the actual concentration does not have to be reported). Although the requirement is in force as from 1 January 2019, the first reporting cycle was started in February 2020). The main motivation for the stricter requirements was to "increase the understanding of how PFAS are used," thereby making it "easier to assess what measures may be necessary to protect health and the environment." An exemption was provided for companies with a turnover of less than 5 million Swedish krona (SEK), which would not have to report information on PFAS. The new rules were replacing a requirement that companies needed to report *all* hazardous substances *and* substances *not* classified as hazardous if the concentrations exceeded 5%. As noted above, the former Swedish rules only captured part of the PFAS in use, since most PFAS are either not classified (although many are suspected to be hazardous) or exempted (i.e., polymers) and most of these potent substances are used in low concentrations (below the previous threshold). However, with the new measure the government would obtain more information about PFAS production and import to Sweden.

The new regulation will provide the Swedish government with a better and more comprehensive overview of domestic use (import and production) of PFAS than it previously had. Some information will, however, still be lacking—for example, the quantity of the PFAS, their exact composition, the volumes transferred through companies with a turnover below 5 million SEK, and, until next year, the presence of PFAS in articles. Nevertheless, with these changes, the PFAS reporting scheme in Norway and Sweden developed quite differently. In the next section we will explore some potential explanations for the differences.

The Nordic PRs facing opposition. The Nordic PRs have been facing opposition, mostly from industry, but also from some parts of the government. The industry has been challenging the PRs both legally and politically. In 2010 the Swedish PR was indicted by a Canadian oil company, challenging its legality (InfoCURIA 2016). The company had received a fine for importing almost 400 tons of chemical products in 2009 without fulfilling its reporting obligations. The lawsuit went all the way to the Supreme Court on the argument that the PR hinders free movement of substances that are covered by REACH and that the register served the same purpose as REACH. The Swedish Supreme Court referred the issue to the European Court of Justice (ECJ), which in turn ruled that "REACH must be interpreted as not precluding national legislation, which makes it mandatory for importers of chemicals to register them with the competent national authority" (Buxton 2016; InfoCURIA 2016).

In Norway, the Federation of Norwegian Industries has been opposing the Norwegian PR on similar grounds (Norsk Industri 2016). In a public hearing, the Federation suggested that the PR should be shut down, arguing that reporting to both the PR and REACH is double accounting, that much of the same information is available through safety sheets, and that the PR is time consuming and resource demanding for the industry (and for the government). A particular concern that was raised by the industry is the risk associated with reporting on the complete composition of chemical products,

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grounded in a fear of industrial espionage. This concern has been frequently discussed between the industry and the government. To reduce the risk, the government has executed numerous detailed control and safety measures through a data protection instruction, including the establishment of a supervising security committee, in which the industry takes part; special safety routines; a separate data and server system to store and process data; and authorization of, limited accessibility for, and training of staff, etcetera (Ministry of Climate and Environment, Norway 2015). To our knowledge, throughout the existence of the product register, no such security breach has occurred.

The existence of PRs has not only been challenged by the industry, but also in the Norwegian government there appears to have been some diverging views on the registry. In 2016, the Ministry of Climate and Environment announced that, as part of the government strategy for improving efficiency, it would consider closing down the Norwegian PR. The Ministry requested its underlying body, the Norwegian Environment Agency, to carry out an evaluation (Ministry of Climate and Environment, Norway 2016). The communication from the Ministry argued that the significance of the PRs had been reduced due to the implementation of EU regulations on chemicals. Interestingly, this was taking place concurrently with the Norwegian government supporting Sweden in the European Court of Justice, arguing that the PR reporting scheme was not overlapping REACH (Buxton 2016; InfoCURIA 2016).

In contrast to the industry position and the new line indicated by part of the Norwegian Ministry, academics and other government agencies (including Norwegian) have voiced in rather strong favor of sustaining the PRs in the Nordic countries. In a workshop hosted by the Nordic Council of Ministers (NCM), gathering scientists and government officials with expertise on PFAS (Nordic Council of Ministers 2018), it was emphasized that the potency, mobility, and small volumes of PFAS needed for various types of use warranted closer surveillance and enhanced traceability. Thus, even though the REACH registration limit was reduced from 100 tons to 1 ton in 2018, it was considered too high to capture registration of relevant volumes of PFAS. As previously described, evaluations carried out by the Swedish government concluded that the reporting criteria of 100 kg used or 5% content in mixtures in Sweden (Sweden previously operated with a 5% limit for registration) was also too high (Enander 2016). The new reporting measures introduced by the Swedish government and the statement from the policymaker workshop hosted by the NCM contended that, rather than closing down the PRs, they should be expanded to include more information about PFAS. So far, the Norwegian government has not taken any further steps on the matter, either to follow up the proposal to close down the Norwegian PR or to strengthen it in line with NCM recommendations.

PFAS challenge current reporting schemes

Our analysis of the PR data on PFAS revealed several developments in use and import that are relevant for effective management of such chemicals. Not only did the data disclose a decrease in the use of PFAS in firefighting foams over the time period, but they also revealed an increase in the use of other PFAS, as well as a more heterogeneous application of these chemicals in various products and processes. What is more important, however, is the revelation that the data available most likely are only the tip of the iceberg. Even though the Norwegian PR is 1 of the most comprehensive chemical registries internationally, a significant proportion of PFAS are still flying under the radar and not being reported or registered. PFAS that are imported in low quantities (<100 kg) or not classified under CLP are, as a rule, not obliged to be registered, although some PFAS are accidentally registered, being constituents of other chemical constituents that are classified as hazardous and above 100 kg. Even substances with PBT and vPvB properties will not necessarily be reported to the PR, since they fall under the REACH regulation and are not directly criteria for CLP (although the toxicity measure may derive from the classification). It seems evident that in order to obtain a complete understanding of the PFAS use and changes in use, and the potential environmental and societal exposure of all PFAS, not limited to those already restricted, a more comprehensive reporting scheme is merited. Sweden has taken a first step in this direction, although key information will remain unavailable—that is, concentration, name of substance, trace levels, PFAS in articles (as from 2021), and substances and/or quantities handled by companies with a low turnover.

The present study has further documented diverging and opposing views on the national reporting requirements. Whereas the industry has advocated for a relaxation of reporting requirements and closure of national reporting schemes such as PR, challenged it in court, and apparently convinced part of the government to consider closing down the Norwegian PR, there has also been a strong push in the other direction. An increasing number of countries, including Norway and the other Nordic countries, are currently pushing for more stringent regulations on PFAS, regulating it as a group rather than substance by substance. In the above-mentioned PFAS policy workshop, set up to explore joint strategies (hosted by the Nordic Council of Ministers in 2017, with key representatives from the Nordic countries, Austria, and Germany), it was acknowledged that necessary information on the use of PFAS is lacking; some are found in the environment although not registered in use, and PFAS-containing polymers, potential precursors, and PFAS-containing articles are missing. Moreover, the recent drive from a large group of European countries to regulate PFAS as a group advocates the need for separation between essential and nonessential use. The argument is that PFAS should only be used for strictly essential purposes in the future. The rapidly increasingly diversity of use throughout the last years demonstrated by our analysis also emphasizes how a robust data registry may contribute to assess and differentiate between essential and nonessential use.

The long history and position of the Nordic PRs are closely linked to the countries' strong position in international governance of chemicals. No single country has been nominating as many POP candidates, including several PFAS, to the Stockholm Convention, as Norway. Together with the EU, and the Nordic countries in particular, they have nominated the vast majority of POPs regulated under the Convention. The documentation of production and use has been very important in this work, not only towards the Convention but also in the development of EU regulation, which often has preceded the global regulation. For instance, when developing a "risk management option analysis" (RMOA), where detailed information on tonnage, uses, and potential exposure is explored, the PR data are particularly valuable. The PR has also been frequently applied when screening for new compounds in the environment, to make a risk-based prioritization and target those chemicals that may be most likely to be detected in the environment. Subsequently these results have been used to promote restrictions under REACH. Recent communications around the new EU chemicals strategy suggest a phase out for PFAS is now at point-blank range—the big battleground will be on defining essential versus nonessential use (Oziel 2020a, 2020b).

These elements underline the unique situation of Norway and the Nordic countries, with their PR as essential toolkits, being frontrunners in the management of hazardous chemicals, not only in sustaining data and providing such data for domestic policy development, but even as a premise for international policy development and future control of PFAS.

CONCLUSIONS

Building on these results we argue that in order to enhance future management and control of PFAS the Nordic PRs will continue to be an indispensable tool. Although there are ongoing discussions within the EU on the reporting limits and whether to include polymers in the reporting requirements, the presumption that REACH registration requirements can in any way replace the Nordic PRs in the foreseeable future seems distant. Hence, rather than loosening the rope on reporting within the Nordic countries, the case of PFAS underlines the importance of tightening existing reporting requirements to obtain necessary information about use, release, and potential exposure of such a detrimental environmental and human health hazard. Such data should be made openly accessible, to the greatest extent possible, allowing public and scientific scrutiny and investigation. Furthermore, the quality of data is also imperative for better control of PFAS use and release. Thus governments should strive for efficient digital and elevated security reporting schemes, with a high level of quality assurance and checks.

It is our view that a comprehensive, mandatory reporting scheme of all use and import of PFAS under the PR will be a critical tool and determinant for sound management of PFAS. It will supplement the scientific knowledge basis with essential industry data on use and volumes, thereby contributing to lower the tremendous financial and bureaucratic burden on governments in controlling the overwhelming body of hazardous chemicals. It may reduce the probability of the industry replacing 1 hazardous chemical with another unregulated, but just as hazardous, one. Lastly, more comprehensive reporting schemes, providing detailed information about trends and shifts in use (e.g., type of use, substance, quantity), will be vital support to future work of differentiating between essential and nonessential use and scrutinizing industry data through quality assurance systems within the PRs (Glüge et al. 2020). Undoubtedly, when it comes to international chemical management and control, the Nordic countries will continue to play a key role within the EU and globally. With the PRs as powerful tools in their pockets, they generate industry data that are essential for sound policy making. Hence shutting down or weakening these national reporting regimes could have global repercussions.

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Data Availability Statement—The data belong to the Norwegian Environment Agency, which has given us access to nonconfidential information of the product register and allowed us to present the data to the public in its present form. Questions about the Norwegian product register can be posed to the Norwegian Environment Agency. Nonconfidential data from the Norwegian product register are publicly available at www.spin2000.net.

SUPPLEMENTAL DATA

The Supplemental Data contain additional data about the PFAS used in Norway, presented in tables, in text about the PFAS used in the largest amounts. Also the PFAS use is presented in more detail in figures where the time trend is treated statistically, and usage and OECD category are also treated statistically.

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