A Fact-Based, Hopefully Non-Panic Inducing Discussion about PFAS and Skiing.
"In comparison to known sources and inputs of PFAS into the environment, cross country ski wax comprises only a miniscule portion. However, in the minds of consumers and the ski community, that portion may be enormously damaging."

By Erik D. Mundahl, P.E.

Any discussion of per- and polyfluoroalkyl substances (PFAS), cross country skiing, and the ski wax industry must be a discussion based on stewardship, ethics, and most importantly scientific fact. Fasterskier and its' journalists and contributors have engaged in a topic that is not only important, but also extremely complex. Due to the proprietary nature of the ski wax industry, the general public is not aware of the chemical makeup of the products they are using, or more recently decrying. I hope that the information presented here will allow for further discussion within the ski community and may help to mitigate some misconceptions. If you find yourself dozing off from boredom, you're probably not alone. To gain an accurate understanding of the issues, we must lay out the facts, and they are extensive.

The Chemistry

As discussed in other articles, PFAS are a family of more than 3,000 man-made fluorinated organic chemicals. These compounds have been produced throughout the 20th century and have been heavily used in nearly every industry. The chair you are sitting on likely has a PFAS stain-resistant treatment. The food you are eating likely utilized a PFAS surface coating on its packaging. The electronic devices on which you are reading this article probably contains PFAS coatings or insulation on some of the electrical components. The vehicle you drive has PFAS treatments on the upholstery, and PFAS was used in the production of many of the interior plastics. Even that rust-proofing that the dealer tricked you into buying, yeah, PFAS. These compounds were found to be so wildly successful at what they do, that they have become integrated into countless aspects of our daily lives.

Some examples of PFAS uses (ITRC, 2017):

- Textiles & Leather
    - Factory or consumer-applied coatings to repel water, oil, and stains. This includes protective clothing, outerwear, umbrellas, tents, carpets, and upholstery. For example, brands like Gore-Tex or 3M Scotchguard.
- Paper Products
    - Surface coatings to repel grease and moisture. Many of these are on food-contact materials such as pizza boxes, fast food wrappers, microwave popcorn bags, baking papers, pet food bags, and myriad other food packaging products.
- Metal Plating & Etching
    - Corrosion prevention, mechanical wear reduction, surfactants, electroplating.
- Wire Manufacturing
    - Coatings and insulation
- Industrial Surfactants

- The manufacture of plastics, fluoropolymers, and rubber. Also manufacture of plumbing coatings, composite resins, and flame retardants.

A number of studies have been conducted on the human exposure pathways to PFAS contaminants. For perfluorooctanoate (PFOA) specifically, one such study found that 66% of our total contribution was attributed to our diet, 24% to tap water, 9% to dust, less than 1% to inhalation, and less than 1% through dermal contact (Tian et al, 2016). These studies often found that our primary exposure pathway was through ingestion of contaminated foods or water. Other exposure pathways, while present, are minor in comparison. Another study found that the concentrations of PFAS in the air were identified in shops selling outdoor clothing, indicating that exposure to outdoor textile products treated with PFAS are a major contributor to indoor air quality (Schlummer et al, 2013).

The military was one of the first to use these compounds, and as a result, military installations globally are among the most prevalent sites where PFAS contamination has been observed in soils and groundwater. Similarly, facilities that have used large volumes of fire-retardant foams such as airports and fire-fighting training centers also are prone to be major sources of PFAS contamination (ITRC, 2017).

Industrial manufacturing facilities have received a lot of attention as PFAS sources. The 3M facilities in Minnesota in particular have been the source of major litigation. Other U.S. and global manufacturing facilities are uncovering PFAS contamination as more and more sites are investigated.

As PFAS has been integrated into so many products we use on a daily basis and is a durable, non-degradable compound, it follows suit that it has been identified in increasing concentrations at places where wastes are accumulated, such as wastewater treatment plants and landfills. Conventional sewage treatment methods have not effectively removed PFAS. Recently in locations where elevated concentrations have been found in waste streams, plants are being modified to efficiently remove these compounds from the environment.

Leachate from municipal landfills has been found to be source of PFAS due to the disposal of consumer products with PFAS treatments (ITRC, 2017). However, modern landfills provide significant protections through the use of leachate collection systems that allow for treatment prior to discharge into the environment. Many landfills effectively manage low-level concentrations of PFAS in leachate today.

The same attributes that make these compounds work well are also the reason they have been identified as problematic in the environment. Carbon-fluorine bonds do not readily degrade. Hence the reason why PFAS was the listed as a Stockholm Convention Persistent Organic Pollutant (among other national and global efforts) which identified these emerging pollutants as potentially hazardous. The PFAS compounds that received early attention in the environmental and industrial hygiene circles were PFOA and perfluorooctane sulfonate (PFOS). These compounds are considered “Long-chain” PFAS or more commonly referred to as “C8”. Long-chain PFAS are compounds with eight or more fully fluorinated carbons. These compounds have been identified through numerous studies to be potentially linked to a wide range of adverse health effects. Lots of information is publicly available on the health issues related to PFAS, so I will not spend time on it here.

Due to concerns regarding potential health and environmental risks, PFOS, PFOA and other long-chain (C8+) compounds are being phased out. By 2008, 3M, the principal worldwide and sole U.S. manufacturer of PFOS, voluntarily ceased production of long-chain PFAS and their precursors. Through the U.S. Environmental Protection Agency (EPA) PFOA Stewardship Program, eight U.S. companies eliminated production of PFOA and it's precursors by 2015. However, these compounds are still commonly imported into the U.S. in all industries. While efforts were made to reduce long-chain PFAS in the U.S., PFAS are still manufactured globally. It is believed that increased production of PFOA and related PFAS in China, India, and Russia has now offset the global reduction that occurred from the U.S. phase-out programs (OECD 2015b).

For the past decade, many manufacturers have been developing replacement technologies, instituting new formulations for their products, including stain and water-proofing coatings, firefighting foams, and clothing. These manufacturers substituted shorter-chain PFAS in lieu of PFOS, PFOA, C8-Fluorotelomer alcohols (C8-FTOH) and other long-chain compounds. These compounds include GenX, C6-FTOH, or PFBS, also known as "C6". Currently, studies are finding that the replacement short-chain compounds may not be less hazardous than their long-chain predecessors. As awareness grows in both industries and regulatory agencies, future studies will provide additional information for the management and use of these replacement compounds.

The Wax

If you're still reading this, you're probably wondering; "So what does this have to do with ski wax?" One of the most frequent questions noted in discussions regarding fluorinated waxes is, "Which waxes contain PFOA (or PFAS, or C8, or 'the dangerous stuff')?" The short answer is that all fluorinated waxes contain PFAS, from fluorinated kick waxes, to low-fluoro hydrocarbons (LF wax), high-fluoro hydrocarbons (HF wax), and pure fluoro powder/block/liquid. All of these products contain varying concentrations of fluorinated carbon compounds, primarily fluorotelomer alcohols (FTOH). Different manufacturers (wax companies) and different products use their own proprietary formulations in waxes. Unless you are in the factory or are a chemist working for the company, its unlikely you will ever know the exact recipe of a fluorinated wax.

To backtrack a little, PFAS are industrial-manufactured compounds. The method through which these man-made compounds are synthesized results in a "dirty" product. Meaning that when a manufacturer attempts to produce PFOA, numerous other related, similar compounds will also be produced. The final product will include an array of compounds including PFAS with four to 16 carbons (C4-C16). Similarly, if one were to attempt to produce a C6 compound, they would also generate an array of other compounds including C4-C16. Manufacturers can work to refine and minimize contamination, but it is challenging, if not impossible, to produce a pure compound. Ski wax companies purchase raw chemical materials from major manufacturers such as Dupont, Mitsubishi Chemical, and many others. The ski industry is not producing PFAS, rather they are purchasing it and using it as a component in their product. Thus, the wax company is dependent on their chemical supplier to ensure they have a pure product.

Currently, fluorinated ski waxes contain a mixture of PFAS compounds generally ranging from C4 to C10 including PFOA, FTOH, and others. Similar to other industries, it has been found that the larger the fraction of C8 in a wax, the better the performance. However, since the raw products are never pure, the C8 compounds will include a mixture of C6 and other length carbon-fluorine chains. Generally, wax companies are not intentionally including PFOA as a component in wax, it is an impurity from the chemical manufacturing process.

So, back to the question of how much PFAS is in a wax. The quantity will vary by brand and type of wax. Naturally, a low-fluoro hydrocarbon will contain less PFAS than a pure fluoro powder. Pure fluoro waxes are often considered "the dangerous stuff". Most skiers have seen the acrid cloud of smoke from the wax room or read about the elaborate air control ventilation systems in the World Cup wax trucks. As a result, the associated pure fluoro waxes are seen as a significant health risk. While it will vary by the wax, some currently produced fluoro powders only contain about 0.0005% PFOA (C8). So, one gram of wax is not one gram of PFOA. It's actually only 0.000005 grams PFOA. The concentrations in HF or LF waxes would be even less.

A Matter of Scale

While the study regarding the impact of PFAS to the health of World Cup ski technicians was widely circulated and globally recognized (Nilsson et. al., 2013), an evaluation of the impacts of PFAS on the environment as a result of cross country skiing has not been well documented. A 2014 study at Uppsala University by Joakim Mesch investigated the impacts of PFAS on soils and surface waters surrounding the Swedish Vasaloppet trail. The Vasaloppet provides a valuable test area as the thousands of annual participants result in possibly the highest density of skiers using PFAS ski waxes in one area, in short duration.

The study found that PFAS concentrations in a reference lake (located away from the trail and presumed uncontaminated) ranged from 0.6 nanograms per liter (ng/L) to 2.3 ng/L. In a potentially-contaminated lake near the trail, PFAS concentrations also ranged from 0.6 ng/L to 2.3 ng/L. Water samples collected from snow melt in a small depression on or near the trail were 21.9 ng/L, clearly showing higher PFAS levels concentrated in snowmelt than in a larger water body (Mesch, 2014).

Several studies have identified that PFAS can be globally transported through atmospheric deposition (the process by which particles move from the atmosphere to the Earth's surface), particularly in northern regions. Several studies have been conducted in remote lakes in Canada and Norway. Those studies detected PFAS concentrations at 12 ng/L (in Canada) and 6.0 to 10.0 ng/L (in Norway) in remote lakes well-distant from any human activity (Stock et al., 2007) (Kallenborn et al., 2004). Mesch's analysis stated that the PFAS concentrations within the lakes near the Vasaloppet trail were within background concentrations. Though while higher levels were observed in concentrated snow melt levels decreased once diluted in the environment. Thus, skiing was not shown to cause a significant impact on water quality.

The Canadian and Norwegian studies have shown that surface water PFAS concentrations in northern regions are detectable as high as 12 ng/L as a result of atmospheric deposition. Mesch's study found that PFAS concentrations in snowmelt following a major race were 21.9 ng/L. Comparing these values to both established regulatory limits for PFAS and to known PFAS contaminated sites is essential to understanding the weight that ski wax holds in terms of total global PFAS contamination.

The EPA issued a Lifetime Health Advisory for PFOS/PFOA (combined or separate) of 70 parts per trillion (70 ng/L) for drinking water (USEPA 2016d). The EPA advisory established a recommended lifetime PFAS exposure limit, meaning a healthy individual consuming the water containing the listed contaminant at or below the prescribed concentration daily throughout their lifetime. This value is advisory only and is not enforceable. The EPA advisory, like all EPA or State criteria is based in peer reviewed science and documented accordingly. Several U.S. States including California, Minnesota, New Jersey, New Hampshire, and New York have set their own, more stringent standards (Minnesota limit is 35 ng/L for PFOA). The snow melt at the Vasaloppet contained PFAS concentrations of 21.9 ng/L. Thus, by the EPA's published advisory, a healthy individual could conceivably consume the snowmelt from the Vasaloppet trail daily throughout their lifetime without anticipated, correlated adverse health effects.

As 3M was the leading global manufacturer of PFAS in previous decades, the subsequent groundwater contamination at and near the production facilities and their waste disposal facilities near Minneapolis/St. Paul Minnesota has garnered significant litigation and attention. Throughout the investigation and cleanup of the sites thousands of public drinking water wells have been sampled and shown to have had detectable concentrations of PFAS. As noted, industrial manufacturing and landfill sites are among the most heavily contaminated for PFAS compounds.

The concentrations observed at the 3M sites that resulted in groundwater contamination for homes and caused potential human health risks are many orders of magnitude larger than what has been observed in snow associated with cross country ski waxes. Groundwater monitoring wells at a 3M manufacturing facility in Cottage Grove Minnesota were found to have PFOA concentrations as high as 846,000 ng/L (USDHHS, 2005). Military bases, firefighting training centers, and airports where PFOA-based fire-fighting foams have been utilized frequently were found to have surface or groundwater PFOA contamination with concentrations greater than 1,000 ng/L.

While studies have shown that cross country ski wax does result in a detectable concentration of PFAS contamination in the environment, those concentrations have been found to be well below current scientifically-based regulatory levels for safe drinking water in the U.S. In fact, the PFAS concentrations are only slightly higher than concentrations occurring from atmospheric deposition which some believe now constitute a global baseline for these compounds. In comparison to known sources and inputs of PFAS into the environment, cross country ski wax comprises only a miniscule portion. However, in the minds of consumers and the ski community, that portion may be enormously damaging.

An Industry Like No Other

While PFAS has found its way into numerous industries and innumerable products, no industry has utilized the name of the compound in the same manner as the ski wax industry. "Fluorocarbons, pure fluoros, fluoro powder"; in the skier's mind, these words are synonymous with speed and performance, after decades of marketing by wax companies. In the 1990s, you wouldn't see Gore-Tex advertising raincoats with the word "Fluoro" emblazoned on the label, but a little bottle labeled "CeraF" at the Birkie Expo still has skiers reaching for their wallets. The ski industry latched onto the fluorocarbon as a wonder-chemical both in practice and in marketing.

As the health and environmental concerns regarding these products gain traction, and environmentally conscious global consumers sway the market forces, the ski industry has been forced to respond. "Fluor Free" is the new catch phrase you'll see splashed across packaging at your local ski shop. Numerous new brands are popping up to fill a niche they see available in the industry as well, positioning themselves as an environmentally conscious option.

Industry giants have not failed to take notice. Toko has rebranded their Low Fluoro (LF) and High Fluoro (HF) brands as "Performance" and "High Performance" for the 2019/2020 ski season. Swix's venerable CeraF line (F stands for Fluoro) is purported to be rebranded as the "Pro Race Coat" for coming seasons. While these products most certainly contain PFAS in some concentration, the companies now see what was once an advertising asset as a major liability.

Where Do We Go From Here?

Beginning July 4, 2020, the European Union will regulate the production, transport, and sale of any products containing PFOA or associated precursor compounds under the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH). All products will be required to contain PFOA (C8) concentrations of less than 25 parts per billion.

This new regulation results in major industry changes for ski wax. The regulatory action functionally eliminates C8-based ski waxes. After July 4th, 2020, all waxes manufactured or sold in the EU will rely sole on the shorter-chain fluorocarbons (C6). As previously mentioned, raw PFAS chemicals compounds are rarely pure and contain an array of fluorocarbons C4-C16 due to manufacturing processes. Developing an EU compliant wax using "pure" C6 is challenging, though several manufacturers claim to be already selling compliant C6 waxes.

The Toxic Substances Control Act (TSCA) has been discussed in good detail in regard to the absence of fluorinated waxes in the U.S. last year. TSCA requires that chemical manufacturers or importers report chemical compounds that are utilized in products. The chemical composition must match or be a functionally similar isomer of a compound that is registered to the TSCA inventory to be legally manufactured or imported in the U.S. Where importers ran into trouble in 2018 was that many of the products they were importing were not being reported to TSCA. That is not to say that those compounds weren't present on the TSCA inventory. In some cases, it was simply that the importer/manufacturer had not made the effort to identify the appropriate inventory registration. In other instances, it was discovered that no similar compounds had been registered.

Generally, the C8 chemistry in many ski waxes has been found to have existing registrations in TSCA and can readily be imported. There are some notable exceptions though. Swix and Toko have both made it known that fluoro powders, blocks, and liquids will not be available in the U.S. this year. This suggests that they have not been able to identify appropriate TSCA registrations and cannot legally import those products. Other manufacturers have encountered similar problems with low fluoro and high fluoro hydrocarbons in solid form.

The lack of an existing registration forces wax companies to do one of two things. They can either attempt to register a new TSCA chemical, an expensive and time-consuming legal process, or they can work to develop a wax that is based on an existing registration. This problem comes to the forefront with the development and use of C6 wax. Far fewer of these compounds have existing TSCA registrations. So, while C6 waxes will be prevalent in Europe in the coming years, it may not be possible to easily import them into the U.S.

Future studies of C6 and other short-chain PFAS may well find that they too cause adverse risks to human health and the environment. It is not inconceivable that the production of all fluorocarbon ski wax will be ended in Europe through regulation in the coming decade. Market forces and a consumer's desire for an environmentally-friendly product may further accelerate the timeline.

A Personal Decision

The risks to human health and the environment from PFAS compounds are extensive and well documented. It's doubtful that anyone in the ski industry would argue against the fact that PFAS, and specifically PFOA (C8) has the potential for significant adverse impacts. Where the issue comes into question is what impact the use of PFAS-based ski wax has on those outcomes. The available evidence so far has found that while fluorinated waxes do leave a detectable footprint on the environment, it is not at concentrations that are known to be potentially hazardous. More investigations into PFAS at major cross country ski venues in the U.S. and Europe would be extremely valuable. Industry partnership in studying those impacts would be beneficial as well.

Until data proves otherwise, it does not appear the risks associated with fluorinated waxes are substantial enough to warrant throwing away your wax, burning your skis, and deciding to start knitting your family's clothing from hemp. It is entirely probable that you are exposed to higher concentrations of PFAS by driving in your vehicle while wearing treated outdoor clothing on the way to the ski race than you are the entire time in contact with a fluorinated ski wax preparing and handling your skis. Further, it would be impractical for sport governing bodies to implement bans on fluorinated waxes due to health and environmental harm, when the data currently does not support that statement or is ambiguous at best. Competition bans of fluorinated waxes for non-health or environmental reasons in junior races or other events are a separate issue entirely.

Any decision on the use of fluorinated ski waxes should be personal and based on your own ethical principles. However, those principles should be guided by facts and a scientific understanding of the issue. The question of how to appropriately handle these waxes should be managed practically. Most households contain a variety of cleaning products, fertilizers, or other chemical compounds that are just as, if not more hazardous, than PFAS. So long as precautions are made, we continue to utilize those products with little ill effect. Once again, it's a matter of scale. In an interview with Scientific American regarding her 2013 study on the health impacts of PFOA on World Cup waxers, Helena Nilsson stated "There is no need to worry too much if one only intends to wax the occasional one pair or two."

If you do choose to use fluorinated ski waxes, ensure that you work in a well-ventilated space, utilize proper respiratory protection (particulate and Volatile Organic Compound filters), wear waxing gloves or other appropriate hand protection, utilize a wax apron, and when done, ensure that you clean your work space and wash your hands. All wax shavings should be sealed in a trash bag and disposed at a permitted community or regional landfill.

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