TITLE:
Forever Chemicals: Understanding Their Origins, Evolution, and Overcoming the Analytical Separation Challenges They Present

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DEK: What are these pervasive "forever chemicals"? They have been around for a long time, and they are everywhere, but why don't we know more about them and how can industry improve detection and measurement capabilities?

LCGC: What are per- and polyfluorinated alkyl substances (PFAS) compounds, and why are we hearing so much about them lately?

Powley: In general, most people have heard about only one of the many PFAS chemicals, perfluorooctanoic acid, commonly known as PFOA or C8. It's the subject of a documentary on Netflix called *The Devil We Know* and the 2019 film *Dark Waters*. They are a class of forever chemicals that are everywhere, and since 2000, there has been concern about them. They do not break down and accumulate (hence "forever") and have been linked to different types of cancers and other health effects. There are concerns about PFOA even at part per trillion levels in drinking water.

LCGC: Where did these compounds originate, and where are they now found?

Powley: All these chemicals are manmade fluorochemicals, so they don't naturally occur—they have to be manufactured in a chemical manufacturing plant. These chemicals are used in a variety of products such as non-stick cookware, fabric coatings to protect carpets, firefighting foams, and other similar products.

As a result of their use over the past 50 years, they are now found everywhere because they don't degrade, and they get around and move through the environment very easily. Just about any water supply that is near a relevant industry can be impacted, be it a manufacturing plant, a brownfield or superfund site, airport, or military base. They are also highly mobile in aquifers and can even show up in arctic animals at the North and South Pole. All humans have some levels of these compounds in their blood serum, typically low part per billion.

LCGC: Why do we not know more about them?

Powley: Prior to the year 2000, the analytical tools we had available such as GC-MS and early versions of LC-MS were not sensitive or selective enough. In the case of LC-MS, it wasn't quantitative. The big game changer was the commercialization of the electrospray interface for LC-MS/MS around 1998.

Once that came out, we could detect even part per trillion levels in water and single digit part per billion levels in blood serum. Water and blood serum are the two major areas of concern. Now that we could measure them accurately and at these low levels, we saw them everywhere.

Beyond instrumentation, there was a lack of standards and issues with contamination in labs and samples. Because these compounds are everywhere, they are used in a lot of laboratory equipment, so it is hard to compensate for or get rid of the contamination. There are fewer than 100 of these compounds that can be measured. More are known but authentic standards are not yet available and several thousand still remain.

LCGC: You've highlighted many challenges, and as we know the list of compounds that need to be measured will only continue to grow, but what is the biggest challenge at the moment?

Powley: There are several. As I mentioned, there are thousands of these compounds in the environment, and we don't know much about them. So, the first thing that needs to be done is to improve non-targeted analytical methods to identify more of them. Then regulatory agencies need to decide which of these thousands we need to measure. This would most likely involve designating certain of them as representative or marker compounds. The next step would be to develop quantitative targeted methods with available analytical standards for all of these.

LCGC: Where is the most opportunity for future advances in measuring PFAS compounds?

Powley: A big opportunity of interest is high-performance liquid chromatography (HPLC) column technology. We need columns that can chromatograph both the long- and the short-chain versions of these—fewer than four, maybe down to two perfluorinated carbon units and all the way up to 20 units.

The challenges with the column technology for the short-chain compounds is getting decent peak shapes and for long-chain compounds is eluting them and getting them off the column in one run. We will have to continue to fight with contamination and background reduction, and we need some better strategies for that because there are so many of these compounds in regular use everywhere. The more we add, the more we'll find in our background due to their ubiquitous nature.

In terms of mass spectrometry, the current offerings are adequate, but the data-processing software could be improved to match the methods. Right now, most of the data-processing software for LC-MS/MS is geared toward pharma because they buy many more instruments than the environmental field. Better data-processing techniques for the environmental workflow could also speed things up quite a bit in terms of timely reporting.