Chip Waste is Forever

PFAS Fact Sheet

CHIPS COMMUNITIES UNITED

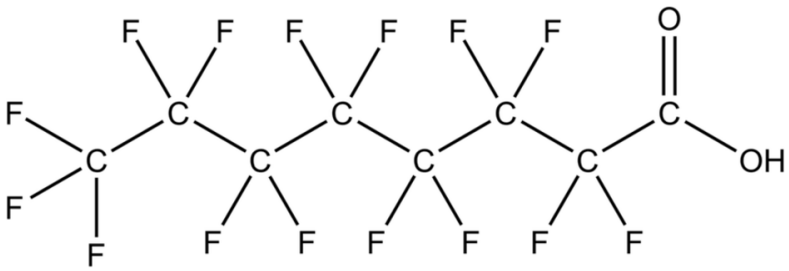
CHIPS Communities United (CCU) calls upon the semiconductor industry—companies that manufacture integrated circuits or microchips—to clean up its act. The industry has a long history of releasing hazardous substances into the environment. Today, manufacturers consider PFAS, dangerous compounds known as "forever chemicals," essential to production, and they continue to release PFAS into their wastewater and the atmosphere.

Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) ***are a family of thousands of highly toxic human-made compounds that are persistent***—that is, they don't break down in the environment.

CCU calls for better management of these chemicals and their replacement, as soon as practical, with safer alternatives.

What are PFAS?

PFAS are molecules characterized by one or more fluorine atoms linked to a chain of carbon atoms. For example, perfluorooctanoic acid (PFOA) is shown below:



PFAS are highly toxic, persistent, and at this point, ubiquitous.

The carbon-fluorine bond is one of the strongest chemical bonds. Because of their durability, these chemicals have been introduced into consumer products (such as Teflon, Scotchgard, and Gore-Tex) and industrial applications. They're also used in fire-fighting foam.

The Dangers of PFAS

It is well established that ***PFAS are highly toxic, persistent, and at this point, ubiquitous***. They tend to accumulate in the bodies of people, fish, and wildlife. The U.S. Environmental Protection Agency reports that, "[c]urrent peer-reviewed scientific studies have shown that exposure to certain levels of PFAS may lead to:

- Reproductive effects such as decreased fertility or increased high blood pressure in pregnant women.
- Developmental effects or delays in children, including low birth weight, accelerated puberty, bone variations, or behavioral changes.
- Increased risk of some cancers, including prostate, kidney, and testicular cancers.
- Reduced ability of the body's immune system to fight infections, including reduced vaccine response.
- Interference with the body's natural hormones.
- Increased cholesterol levels and/or risk of obesity."

PFAS compounds with six or more carbon atoms, known generally as long-chain, tend to be extremely toxic, while shorter chain molecules are less toxic but still not safe, comparable in toxicity to better-known pollutants like trichloroethylene (TCE) and hexavalent chromium. Shorter PFAS compounds tend

to be more mobile in the environment and harder to remove from water. Use by the US military of PFAS-based foam to extinguish jet-fuel fires (most often for training) has contaminated groundwater at hundreds of sites in the U.S. and overseas.

PFAS in chip-making: a thousand different uses

The semiconductor industry has identified over one thousand uses of PFAS in manufacturing and its supply chain. In the words of the manufacturers, "PFAS articles possess a unique set of characteristics required for certain semiconductor manufacturing processes, including inertness, purity, chemical and permeation resistance, a wide range of temperature stability, a low coefficient of friction, electrical properties, bacterial growth resistance, nonflammability, and a long service life (>25 years)."

There are no proven alternatives for most of those uses, and the industry says even where an adequate substitute is found, it typically takes three to four years to put the change into practice. Manufacturers have replaced long-chain PFAS such as PFOS and PFOA (eight-carbon chains) with short-chain compounds such as PFBS and PFBA (four-carbon chains).

The PFAS used in semiconductor production can be divided into three broad categories: process chemicals, fluorinated gases, and fluoropolymers.

Process chemicals: the toxics that can end up in our water or food

Manufacturers use PFAS in wafer fabrication (the central process in chip manufacturing), using chemicals known as top anti-reflective coatings and photoacid generators, for example. The companies do not identify the chemical composition of most of these products, claiming that it's confidential business information. They even say that they don't always know what's in the commercial products they use.

But analyzing what comes out of the factories reveals extensive uses of PFAS. The GlobalFoundries plant in Essex Junction, Vermont, for example, recently reported combined discharges of targeted PFAS of about 400 parts per trillion in its wastewater, which flows into the Winooski River. The company used EPA's Method 1633, capable of measuring 40 specific PFAS. Looking even more closely at the effluent from three fabs, Cornell University scientists found that alongside PFAS chemicals that were previously known and identified, factories were releasing much larger concentrations of what we call "Dark PFAS." These were a combination of purchased chemicals used in the manufacturing process and new molecules created during production.

Few jurisdictions require the measurement of PFAS in semiconductor plant wastewater, and much of the required sampling that exists focuses on PFAS compounds the industry no longer uses.

On the positive side, the Commerce Department announced in November 2024 that it expects to contract for third-party analysis of chipmaking effluent. It also announced research funding into improved analysis and monitoring technologies through the PFAS Reduction and Innovation in Semiconductor Manufacturing (PRISM) program.

On the negative side, ***there are currently no regulatory limits on chipmaking PFAS discharges at the federal, state, or local levels. Chip factories are not required to remove PFAS from their waste streams, so they can legally release the toxic chemicals into rivers, lakes, and streams or send them to wastewater plants that are not equipped to remove PFAS.*** Those plants release PFAS into surface waters or send them off site in their biosolids (sludge), some of which is used as fertilizer on farms. Studies show that ***PFAS released into wastewater often ends up in drinking water.***

In draft Environmental Assessments, some of the major chip manufacturers applying for CHIPS Act funding promised to separate PFAS-containing waste from other liquid waste and send it off-site for treatment. Those documents, reinforced by the CHIPS Office community impact reports issued along with grant agreements, did not explain how PFAS liquids would be separated from other chemicals in the voluminous wastewater or how off-site facilities would destroy the PFAS safely and completely.

Technologies exist for removing PFAS from wastewater, but they don't necessarily capture all PFAS, particularly short-chain compounds. Incineration, the most common form of treatment, may release toxic products of incomplete combustion. Driven by the Defense Department's need to destroy large quantities of PFAS-based firefighting foam, new technologies are being developed to remove and destroy PFAS. Some of those technologies are good candidates for treating PFAS-laden chipmaking wastewater before it mixes with other wastes, but industry is unlikely to employ them unless required to halt its PFAS discharges. And removing PFAS from wastewater after it is diluted with other waste streams is generally impractical and prohibitively expensive.

Fluorinated gases: the toxics that end up in our air

Fluorinated gases used in chip-making include perfluorocarbons, short-chain PFAS, and gases that don't contain carbon such as sulfur hexafluoride and nitrogen trifluoride. All are potent, persistent greenhouse gases (GHGs) which contribute to climate change. ***Fluorinated gases are thousands of times more potent than carbon dioxide, and have lifetimes of hundreds to thousands of years.*** Fluorine-containing gases can also transform into PFAS byproducts, even when they aren't PFAS themselves.

In 2023, electronics manufacturers in the U.S. (mostly semiconductor producers) reported releasing fluorinated gases with a climate impact of 4.4 million metric tons of CO_2. That amount, which does not include the greenhouse gases emitted from the production of energy used in electronics manufacture, is equivalent to the climate impact of over a million homes. Under international pressure to reduce GHGs, companies are looking for ways to reduce emissions. Taiwan Semiconductor Manufacturing Corporation (TSMC) proposes to employ point-of-use abatement technologies at its new Arizona plant to reduce fluorinated GHGs by 90%. But existing approaches are costly, space-consuming, and difficult to retrofit. They release pollutants that require additional treatment. In fact, some of the PFAS byproducts end up in the facilities' liquid waste streams.

Fluoropolymers: still hazardous

Fluoropolymers are another subset of PFAS, formed by combining identical PFAS molecules. EPA considers them less hazardous than non-polymer PFAS.

These compounds, confusingly known as PFA, are found throughout wafer-fab plants in equipment and piping. In 2023, the CEO of chemical giant Chemours explained, "you cannot make chips without a whole PFA infrastructure… We estimate that in a modern-day fab, there's a half-kilo of PFA in every square foot. So in a 400,000- to 600,000-square-foot fab, that's 200 to 300 metric tons of this stuff." (For a sense of scale, the first of TSMC's three planned fabs is 3.5 million square feet, requiring 1,750 metric tons of PFA, the weight of more than a thousand cars.)

In August of 2024, as the CHIPS and Science Act was driving the expansion of existing chip fabs and the construction of many more, Chemours expanded production of Teflon resin at its infamous Parkersburg, West Virginia factory, "to meet rising semiconductor-driven demand."

PFA is particularly hazardous during production and at the end of its useful life. An international group of

researchers found:

> The evidence reviewed in this analysis does not find a scientific rationale for concluding that fluoropolymers are of low concern for environmental and human health. Given fluoropolymers' extreme persistence; emissions associated with their production, use, and disposal; and a high likelihood for human exposure to PFAS, their production and uses should be curtailed except in cases of essential uses.

Recommendations

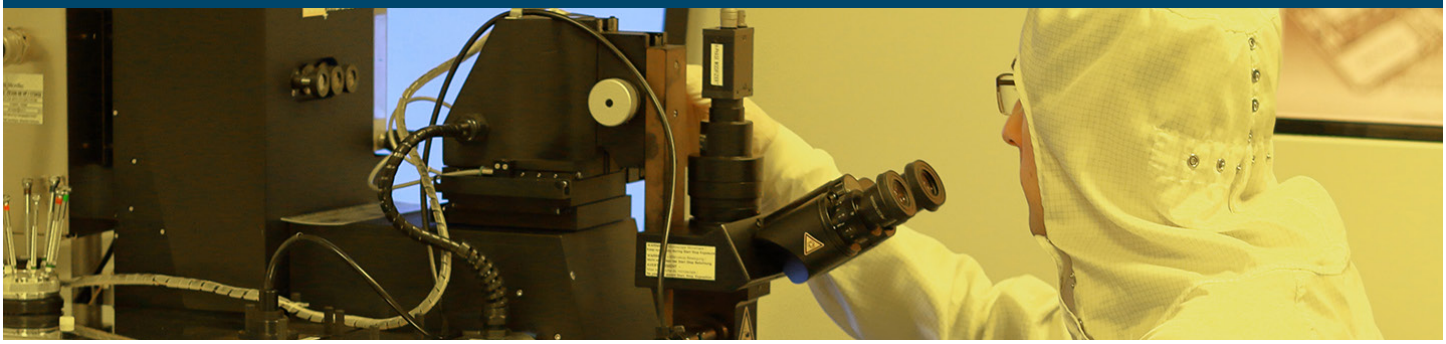
1. **REPORT:** The semiconductor industry should be required to measure and publicly report, for each fab, its use and release of **all** PFAS into the environment, as well as potential workplace exposures. Chemical analysis needs to be expanded to include both targeted and non-targeted PFAS. Workers and communities have a right to know about the toxic chemicals used in chip-making.
2. **DEVELOP ALTERNATIVES:** Industry and government should devote additional resources to developing environmentally superior substitutes for **all** forms of PFAS in semiconductor production.
3. **REMOVE AND DESTROY:** Companies should be required to remove and destroy **all** PFAS from their waste streams, as much as practically possible, and should not simply transfer the pollution to other communities with waste disposal sites.
4. **PREVENT END-OF-LIFE RELEASES:** Programs should be put in place to prevent the environmental release of fluoropolymers and other PFAS at the "end of life" of electronic equipment.

These recommendations should apply to all PFAS, because the toxicity, fate, and transport of most PFAS compounds are unknown. Industry continues to introduce new PFAS into its processes and products, so a blanket response is required to keep the public safe. And waste treatment may create new forms of PFAS that could be more hazardous than the initial compounds. It's vital that efforts to address the threat of PFAS include all members of the toxic forever chemical family.

The widespread use of these compounds constitutes a large uncontrolled experiment on people and other inhabitants of planet Earth. They must be phased out as quickly as possible, and until that happens, they must be removed from industrial waste streams and fully destroyed.

Take Action

Join us today by scanning the QR code or clicking on the url link: **https://bit.ly/4a4qJE4**



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