PFAS Discharges from a Typical Semiconductor Plant
GlobalFoundries, Essex Junction, Vermont

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The CHIPS and Science Act, touted by President Biden and other Democratic Party leaders as a way to provide good, domestic manufacturing jobs, provides an opportunity to clean up the semiconductor industry. Chipmakers have a long history of environmental pollution, dating back to their early days of production in California's Silicon Valley in the 1950s.

Semiconductor manufacturers say that their use of numerous PFAS (perfluoroalkyl and polyfluoroalkyl substances)—so-called "forever chemicals"—is essential to integrated circuit production, but one doesn't see references to discharges and emissions of those persistent, toxic, and bioaccumulative compounds in the press releases announcing massive state and federal subsidies for new and expanded manufacturing facilities. In fact, the draft environmental assessments issued thus far by the U.S. Commerce Department's CHIPS Program Office conclude that those toxic releases will have no significant environmental impact.

Chipmakers are not the largest releasers of PFAS into the environment, but their environmental practices are significant because they consider PFAS use necessary throughout their manufacturing process and their products are considered essential to our economy, national security, and indeed, our daily lives. That is, America may eliminate PFAS from hamburger wrappers and even fire-fighting foam, but in the absence of better environmental management, PFAS from chip production will continue to add to the already unacceptable load of PFAS in our workplaces, environment, and even our bloodstreams.

Today there are no limits on the industrial discharge of PFAS from semiconductor plants. Understandably, state and federal environmental regulators are focused on the massive PFAS releases from chemical plants and military airfields. In fact, little has been known about PFAS pollution from chip wafer fabrication factories. To some degree, it's a different problem, focused on other compounds than those that have made the news.

Now, thanks to the attention of Vermont environmental regulators and a couple of published studies from Cornell University, we are starting to see behind the veil of semiconductor industry opacity.

GlobalFoundries' "Fab 9" factory in Essex Junction, Vermont, originally part of IBM, is a typical semiconductor plant. In June 2021, the Vermont Department of Environmental Conservation (VDEC) issued a Discharge Permit to the company allowing it to continue discharging treated wastewater into the Winooski River, which flows to Lake Champlain. The permit fact sheet illustrates the company's sophisticated treatment system.

Unfortunately, like most—perhaps all—chip plants in the U.S., Fab 9 is not required to remove PFAS from its waste stream. Most other chip plants discharge water into sewage systems, but the public wastewater plants that receive the sewage are likewise not required to remove PFAS, so the contamination is released into surface water and biosolids, much of which are applied to agricultural land.

In the 2021 permit, VDEC required GlobalFoundries to measure five of the most common PFAS compounds in its "final effluent," shown in the diagram as "to river." It found measurable levels of all five. Consequently, to its credit, VDEC sent a letter to the company in October, 2023 requiring it to sample for about 25 additional PFAS, using U.S. EPA's Method 1633. Thus far, GlobalFoundries has submitted three quarterly reports. I have summarized the results, showing only the substances detected, in the table below. The asterisks denote measurements reported in the original 2023 annual report but which were not included in the quarterly reports.

The principal conclusion is obvious: The total of targeted PFAS measured using Method 1633 is seven times as high as the total of the five compounds listed in the 2021 permit—and shown in *italics* in the table below. But academic researchers, using more sophisticated analytical techniques to measure semiconductor plant wastewater, have found much higher levels of "non-targeted" PFAS, what should be known as "**dark PFAS**."

In fact, if one takes into account the PFAS not measured by Method 1633, they could be 70 times as high as for the five listed compounds.[1] For the most recent reporting quarter, that would mean that GlobalFoundries is releasing PFAS into the Winooski River at a concentration more than 4,000 nanograms per liter (ng/L). There is no Vermont or federal discharge limit, but local activists using a commercial laboratory PFAS found targeted PFAS in the river, about a mile downstream from the GlobalFoundries outfall, at 8.3 ng/L. That is near or above the new federal drinking water standards, depending upon the compound.

PFAS in Final Effluent (nanograms/liter, or ng/L)	**4Q23**	**1Q24**	**2Q24**	**Average**
Perfluorobutanoic Acid (PFBA)	145.00	105	130	126.67
Perfluoropentanoic Acid (PFPeA)	56.20	37	48.6	47.27
Perfluorobutanesulfonic Acid (PFBS)	53.20	43.4	43.6	46.73
Perfluorohexanoic Acid (PFHxA)	38.20	28	36.5	34.23
Perfluoro-3-Methoxypropanoic Acid (PFMPA)	26.60	15.7	32.1	24.80
Perfluorooctanoic Acid (PFOA)	*20.00*	*16*	*22*	*19.33*
Perfluoroheptanoic Acid (PFHpA)	*20.10*	*14.6*	*18.7*	*17.80*
Perfluorononanoic Acid (PFNA)	*13.50*	*10.1*	*14.2*	*12.60*
N-Ethyl Perfluorooctanesulfonamidoacetic Acid (NEtFOSAA)	2.33	3.23	32.1	12.55
Perfluorodecanoic Acid (PFDA)	7.33	5.74	10.7	7.92
Perfluoroundecanoic Acid (PFUnA)	4.74	4.89	9.75	6.46
Perfluoro-4-Methoxybutanoic Acid (PFMBA)	5.95	3.48	5.65	5.03
Perfluorododecanoic Acid (PFDoA)	1.95	1.74	5.31	3.00
Perfluorooctanesulfonic Acid (PFOS)	*1.50**	*1.49*	*2.66*	*1.38*
Perfluorooctanesulfonamide (PFOSA)			3.38	1.13
Perfluorotridecanoic Acid (PFTrDA)			2.09	0.70
Perfluorohexanesulfonic Acid (PFHxS)	*1.50**	*?*	*?*	*?*
Total of Method 1633 compounds	398.10	290.37	417.34	368.60
Total of five regulated compounds	*56.60*	*42.19*	*57.56*	*52.12*
Regulated as percentage of Method 1633 total	14.22%	14.53%	13.79%	14.14%

The data does not adjust for the toxicity, mobility, or treatability of each PFAS. In fact, for most PFAS, little is known about such qualities. While it's important to understand better each PFAS compound used by industry, manufacturers are introducing new PFAS compounds faster than they can be studied.

[1] See Paige Jacob, Kristas Barzen-Hanson, and Damian Helbling, "Target and Nontarget Analysis of Per- and Polyfluoralkyl Substances in Wastewater from Electronics Fabrication Facilities," *Environmental Science & Technology,* February 16, 2021, https://pubs.acs.org/doi/10.1021/acs.est.0c06690. This study was supported by the semiconductor industry. See also Helbling's presentation and Hughes/Siegel presentation at the 2024 Healthy Waters Conference at https://www.youtube.com/@healthywaters_coe/videos.

The Vermont data is the tip of the environmental impact iceberg. Here is what is needed:

- All semiconductor plants should be required to report publicly their discharges of all PFAS into wastewater, using not only Method 1633 but measurements of total organic fluorine.
- Manufacturers should be required to remove PFAS from their wastewater, using treatment technologies designed to remove all PFAS, regardless of carbon chain length or formula.
- Media containing the removed PFAS should be treated using methods proven to destroy all PFAS and not create products of incomplete combustion or other toxic byproducts.
- To the degree that current monitoring and treatment technologies are inadequate to meet such requirements, the federal government should support research and development to achieve such goals, on a level commensurate with the funding provided to support semiconductor production.
- The CHIPS Office, working with other federal agencies, as well as representatives of affected communities, production workers, and environmental organizations, should develop and fund research and development designed to reduce, in a reasonable time frame, the use and release of PFAS in semiconductor production. This research should be funded at a level commensurate with the funding provided to support semiconductor production.

The Vermont data reinforces the already obvious need to match investments in semiconductor production with investments to minimize the hazardous impact of such production on workers, neighbors, and the environment.