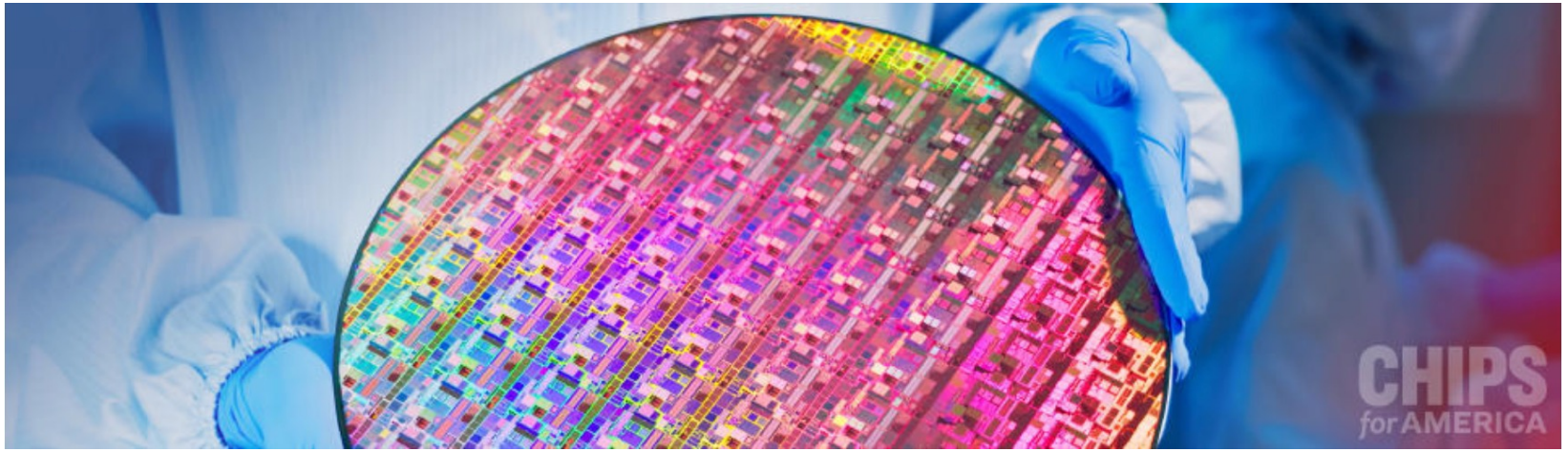
PFAS: “Essential” for Semiconductor Production



LENNY SIEGEL
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Chips—integrated circuits—are considered essential to our economy, national security, and daily life.

Chips are among the most complex products ever created by humanity. Their production process is equally complex.

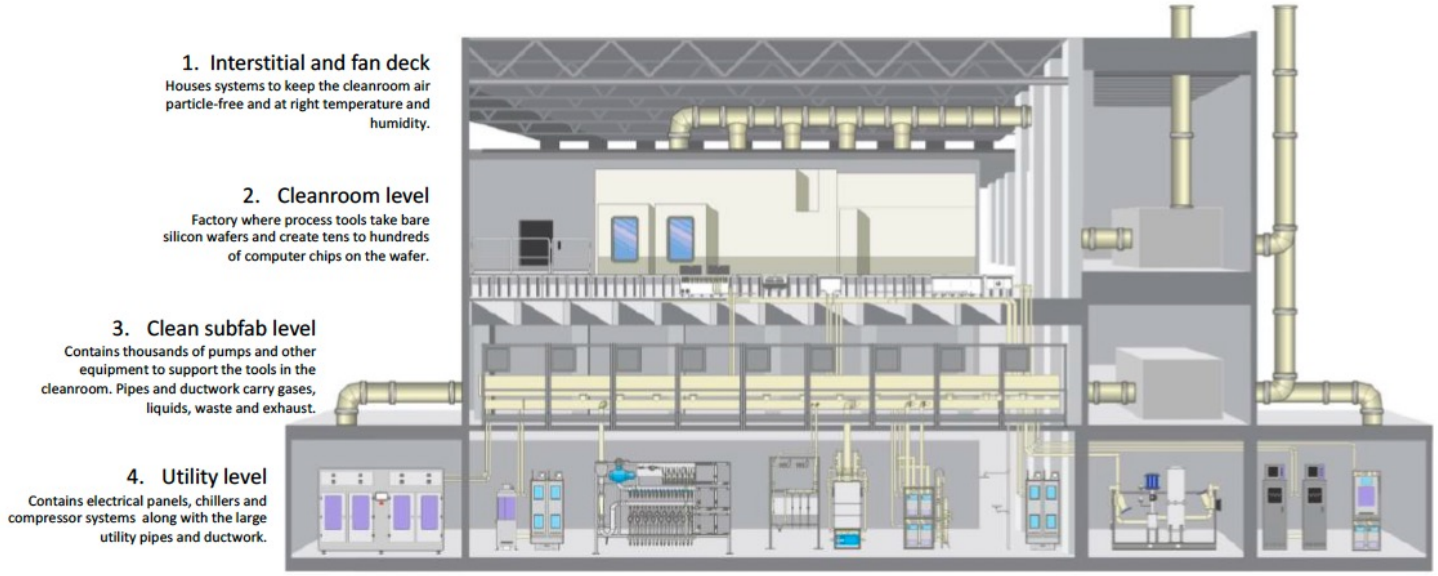


Figure 6: Example semiconductor manufacturing facility layout (CPS an Exyte Group Company 2019).

The chipmaking industry has become reliant on PFAS without first examining the human and environmental risks. It explains, “Without PFAS, the ability to produce semiconductors (and the facilities and equipment related to and supporting semiconductor manufacturing) would be put at risk.”

More than 50 uses, including:

- Photoacid generators
- Top antireflective coatings
- Heat transfer fluids
- Fluorinated gases in plasma processes

LONG-CHAIN PHASE-OUT

The semiconductor industry phased out PFOS by end of 2016.

It plans to stop using PFOA by end of 2025.

The replacements are short-chain PFAS, particularly PFBS.

Industry assumes that short-chain PFAS are much less hazardous than long-chain.

WASTEWATER

CHIPS Program Office at the Department of Commerce observed, in its first environmental review of semiconductor production: “Wastewater discharge from semiconductor manufacturing facilities presents the greatest risk for PFAS contamination of the environment.”

There are a few guidance values for PFOS and PFOA in wastewater, but in general PFAS in industrial effluent, wastewater plant influent, and wastewater plant effluent are unregulated.

PFAS-containing wastewater should be intercepted and/or treated close to its source, where flows are typically lower and concentrations higher.

Using wastewater discharge permits, publicly owned wastewater plants may be able to require pre-treatment at the point of use, and industry may be willing.

WASTEWATER CHALLENGES

PFAS that enters wastewater treatment plants enters the environment (and stays) through liquid effluent and biosolids (sludge).

Industry does not identify all the PFAS it uses.

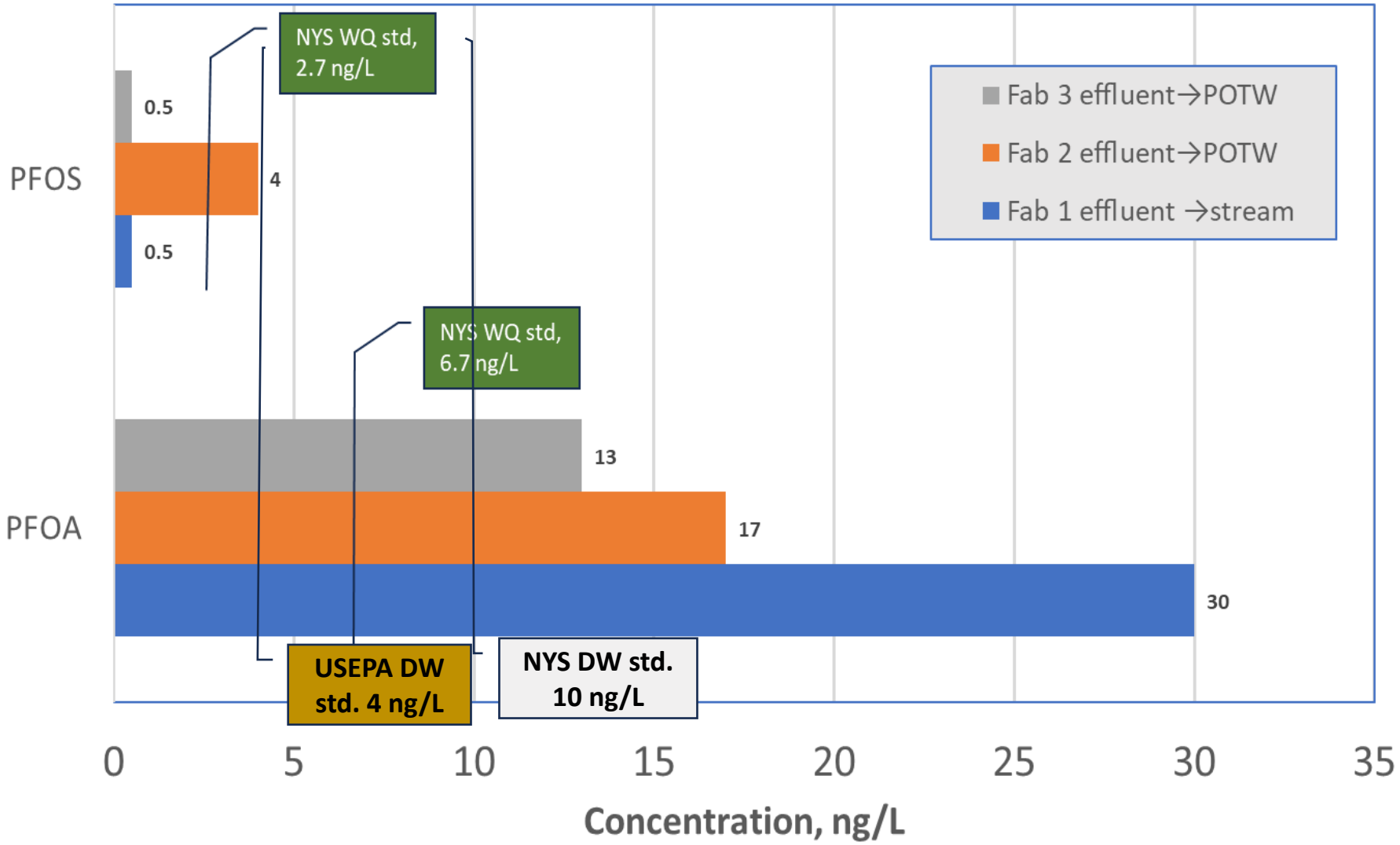
Non-targeted PFAS substances represent a majority of PFAS in chip plant effluent.

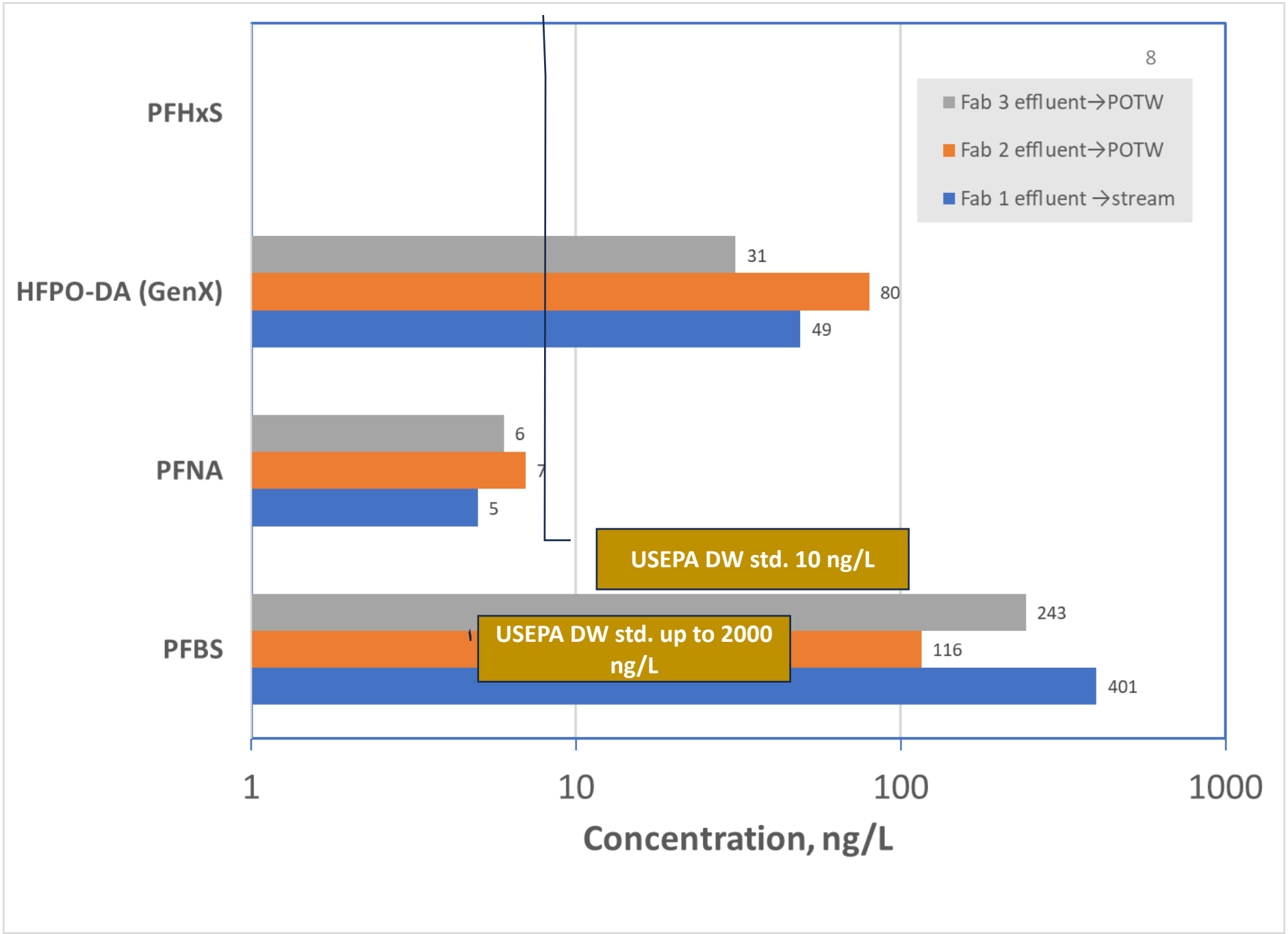
Standard methods do not measure all PFAS.

Filtration systems may not remove all PFAS from wastewater.

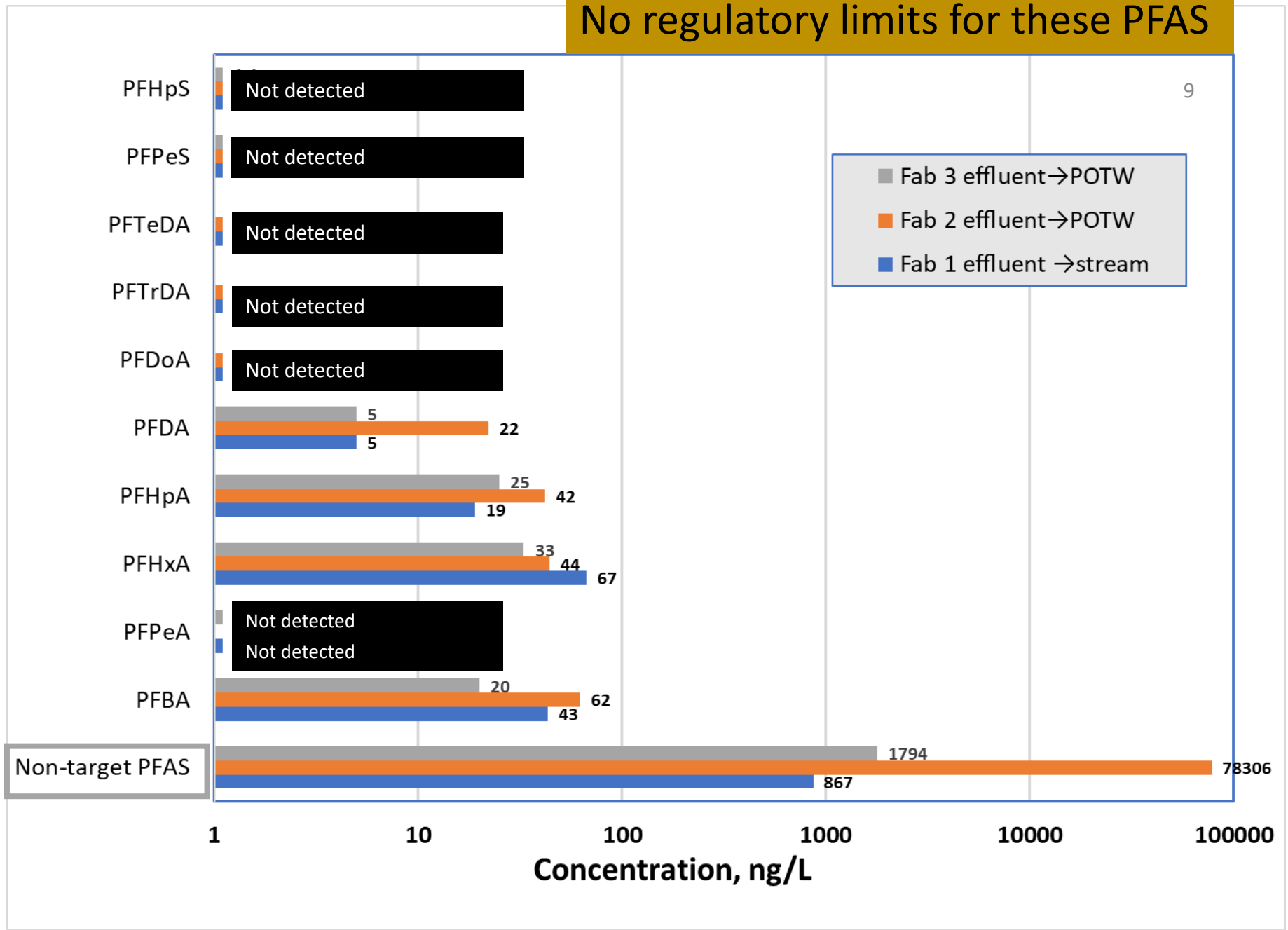
Incineration is the most common method of destroying residue. It may not destroy all PFAS.

Effluent from Three Fabs




PFHxS
HFPO-DA (GenX)
PFNA
PFBS
8
Fab 3 effluent→POTW
Fab 2 effluent→POTW
Fab 1 effluent →stream
31
80
49
6
7
5
USEPA DW std. 10 ng/L
243
USEPA DW std. up to 2000 ng/L
116
401
1
10
100
1000
Concentration, ng/L

No regulatory limits for these PFAS



UNTIL PROVEN OTHERWISE, I BELIEVE:

All PFAS are persistent.

Most PFAS bioaccumulate.

While not necessarily as toxic as PFOA and PFOS, other PFAS are likely to be at least as toxic as other chemicals we regulate in water.

So we need pre-treatment that removes **all** PFAS.

Measure total organic fluorine as well as common PFAS analytes.

Install pre-treatment systems for point of use based on laboratory analysis of effluent. Design for upgrades as new treatment methods are proven.

PFAS regulations for wastewater treatment should be technology-based, using technology developed through state-of-the-art PFAS research.

FLUORINATED GASES

Used in plasma etch and chamber cleaning, they are the largest source of greenhouse gas emissions from semiconductor wafer fabrication.

“1 kg of SF_6 has the global warming impact of >25,000 kg of CO_2.”

“Fluorinated gases have the longest atmospheric lifetime of any of the greenhouse gases, up to 50,000 years.”

“With increasing chip complexity, gas usage rates will likely increase faster than per-chip estimates.”

ADDRESSING FLUORINATED GASES

"F-gas reductions have been achieved through … abatement that destroys PFCs so that they are not released to the atmosphere. Abatement devices can break PFCs into smaller chemical byproducts but may have high CO_2 and create criteria air pollutants such as SOx, NOx, CO and hazardous and toxic air pollutants such as F_2, COF_2, and HF, that require additional abatement."

"Remote NF_3 cleans greatly reduced F-GHG emissions; however, they generate substantial fluorine and HF emissions that require additional abatement and generate CF_4 if carbon sources such as TEOS or an organic low-k is present in the chamber."

POLITICAL CHALLENGES

The semiconductor industry and government agencies consider much of the data on PFAS use and release to be Confidential Business Information.

Industry has introduced many (hundreds of?) PFAS compounds into wafer fabrication without proving them safe.

EPA: “We have developed a framework for new PFAS which will ensure their continued availability for sectors like the semiconductor industry.”

The semiconductor industry continues to lobby for exemptions from the National Environmental Policy Act and other regulations.

THE OPPORTUNITY

Government funding and public awareness have created the conditions to:

Establish regulatory oversight of the PFAS used by the semiconductor industry.

Support research on improved monitoring and treatment of PFAS in semiconductors, as well as the development of safe substitute compounds.

Require best management practices in the measurement, removal, and destruction of PFAS in wafer fabrication, as well as the introduction of safe substitutes.

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See http://www.cpeo.org/chips.html for our articles on the semiconductor industry, including its impact on the environment, the domestic production workforce, and the global assembly line.

Let me know if you would like to join the ChipPFAS e-mail list . There is no cost or obligation.