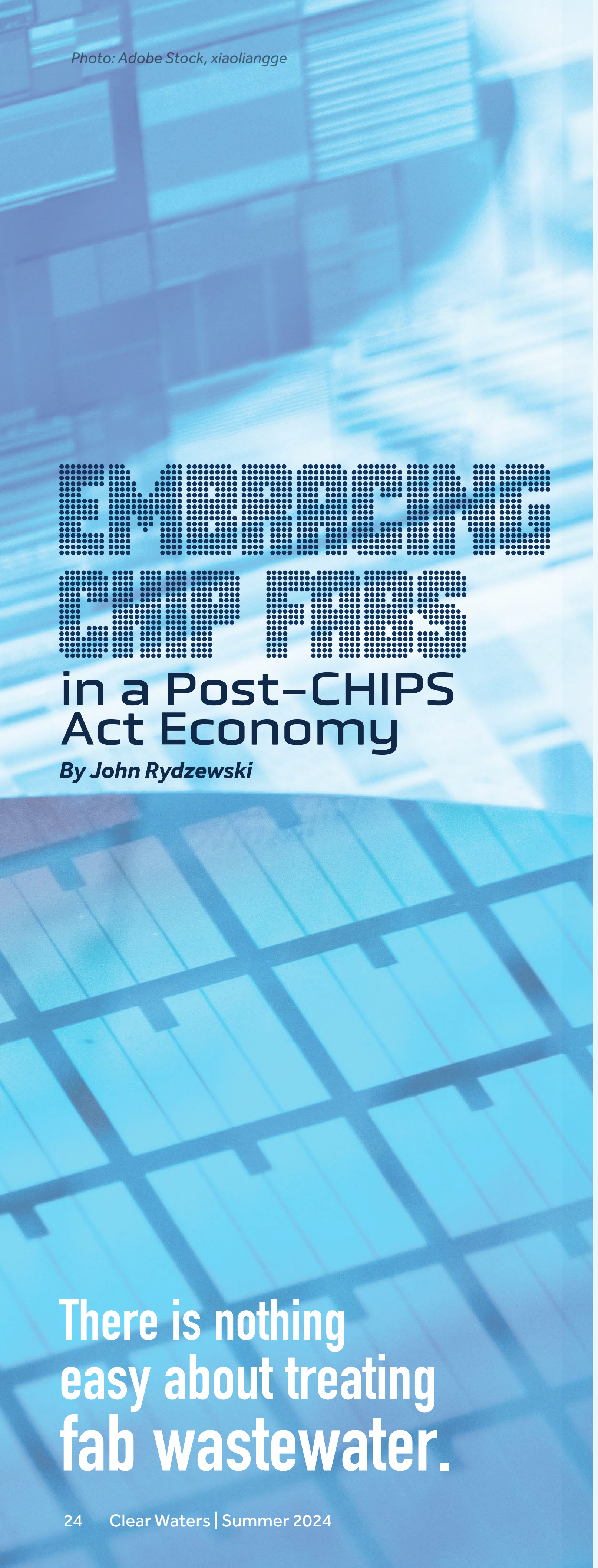

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Embracing Chip Fabs in a Post-CHIPS Act Economy

By John Rydzewski

There is nothing easy about treating fab wastewater.

With the CHIPS Act of 2022 spurring domestic investment in semiconductor manufacturing, more municipalities are finding themselves on the receiving end of a new fabrication (fab) campus or pending fab expansion. These projects bring hundreds of millions of dollars of economic stimulus and tens of thousands of direct and indirect jobs to their respective communities. The overall positive economic impact of a fab project cannot be understated, and these projects have forever changed the economic trajectory of many communities for the better.

However, once the initial excitement has passed, the reality sets in for the municipality that must provide the services required to support the fab. Although welcome from an economic development standpoint, a new fab project could otherwise be a scary proposition for some municipalities. This is particularly true relative to the water and wastewater infrastructure upgrades needed to support the project.

Water Demands and Wastewater Discharge

According to the Institute of Electrical and Electronics Engineers (IEEE), the average semiconductor fab requires between 5 and 10 million gallons per day (mgd) of freshwater to enable wafer production for a single fab—and many semiconductor manufacturers are planning for more than one fab per campus (*Johnson 2022*). For example, Micron's campus in Clay, New York, has plans for four fabs and is forecasting a water demand of approximately 50 mgd at full buildout. By comparison, all of the freshwater users in the City of Syracuse today withdraw approximately 40 mgd. Although the numbers are high, providing this volume of water to a fab project is relatively straightforward, assuming available water resources. Where things get complicated is on the wastewater side of the equation.

Almost all freshwater entering a fab will leave as wastewater, and that wastewater needs to go somewhere. For perspective, as of Feb. 15, 2023, of the 622 National Pollutant Discharge Elimination System (NPDES) permits issued to New York state municipalities, only 39 of those permits are for 15 mgd or greater (*NYSDEC 2023*). Therefore, almost every municipality in New York that has or may secure a fab project will need to upgrade their water resource recovery facilities (WRRF) to accommodate the project.

Timing is Everything

But building or expanding a WRRF to handle fab wastewater is not as straightforward as expanding to accommodate traditional municipal flows associated with population growth. For starters, it is critical that the WRRF is designed and constructed in time to intercept the fab "need date." Otherwise, the fab will not be able to produce chips. Many semiconductor manufacturers—or any manufacturer for that matter—will wait until the last possible moment to publicly announce the siting of a new fab.

While it may take two to three years for a fab project to go from announcement to first wafer, that may not be sufficient time for a municipality to expand their infrastructure to enable fab operations. Municipal construction projects tend to require more time to complete than private projects. The time gap between the first wafer production date and the completion date of the WRRF, if one exists, could be tens of millions of dollars in lost revenue for the fab. Therefore, it becomes critical that the semiconductor manufacturer, the municipality, and the authorities having jurisdiction (e.g., New York State Department of Environmental Conservation [NYSDEC], New York State Department of State) have a strong, trusting relationship to navigate and close any potential gap in schedules before they occur.

Wastewater Quality Challenges

Adding to the challenge is that fab wastewater is unlike municipal wastewater. Typical municipal wastewater contains sufficient nutrients to support a biological treatment process, so the biology thrives, and the treatment process runs efficiently. Typical fab wastewater quality, on the other hand, can hinder or kill the biology tasked to treat it, with close to zero biochemical oxygen demand (BOD), significant chemical oxygen demand (COD), trace metals, fluoride, hydrogen peroxide and several types of azoles, amongst other contaminants. Bottom line: there is nothing easy about treating fab wastewater.

Further complicating the issue is that the fab wastewater at first wafer will often not be the same quality used to develop the design of the WRRF due to the chip manufacturer optimizing the process recipe that will run in the fab. This represents another example where a strong, trusting relationship between the semiconductor manufacturer, municipality and authorities having jurisdiction will be critical for mutual success.

Fast-forward several years to when the fab is up and running and the WRRF is providing high-level treatment of the fab wastewater. Whereas typical municipal wastewater offers relative predictability, steady state is a fleeting condition for a WRRF servicing a fab campus. The chip manufacturing process continues to evolve in complexity, and fabs are regularly increasing the number of unique chemicals that are used at scale. In some cases, these chemicals cannot yet be measured using otherwise standard techniques or laboratories; in other cases, the chemical will challenge the WRRF and its treatment processes or operation.

For example, tetramethylammonium hydroxide (TMAH) is used as a developer in the photolithography process to print the patterns for the transistors and circuits onto the silicon wafers. TMAH can be a major contributor of COD in fab wastewater, but when fab wastewater containing TMAH is measured using a typical COD analyzer, the properties of the TMAH molecule are such that the COD analyzer will not accurately read the TMAH in the analysis. The biology in the WRRF will experience the COD load from TMAH, but the analyzer will not see it. And while traditional COD analyzers are blind to TMAH, hydrogen peroxide in the fab wastewater will bias a COD reading, resulting in a higher than actual concentration of COD. To help overcome these challenges, it becomes critical for the WRRF to understand the individual constituents in the fab wastewater being discharged.

As if those challenges were not enough, there is a family of fab wastewater constituents that will pass through most municipal wastewater treatment plants: total dissolved solids (TDS). A sizable fab campus could discharge well over 100,000 pounds of TDS per day from various operations including chemical use in the fab, pH adjusting of scrubbers, ion exchange resin regenerations for ultrapure water production and wastewater pretreatment, as well as pH adjustment of the blended, pretreated wastewater prior to discharge to the WRRF.

In recent years, an increasing number of WRRFs, to comply with their NPDES permits, are being asked to monitor their TDS discharges, even if the WRRF is discharging into a relatively large water body where salination may not appear to be a concern. This includes at least six municipalities in New York state. When a TDS monitoring requirement is implemented, it is safe to assume that TDS control will follow. In more arid regions of the U.S. where treated municipal effluent is reclaimed and reused for irrigation and non-potable industrial uses, such as Arizona, TDS limits are the norm, and semiconductor manufacturers in those areas have invested heavily in TDS control. It is only a matter of time before TDS control becomes a standard treatment process at all chip fabs.

Because of the large volumes of water required by a fab, there is public pressure on the industry to reduce its water footprint. Compounding matters is that freshwater resources in many parts of the country are constrained: 38% of the 108 existing and announced fab sites the U.S. in 2023 are in regions with high or extremely high water stress, as defined by the World Resources Institute (www.wri.org). Therefore, as most semiconductor manufacturers continue to pursue their water sustainability commitments by reducing freshwater use and reclaiming and recycling their wastewater, the concentration of TDS discharged from the fab will continue to increase. Almost all major semiconductor manufacturers have at least one fab campus where they are operating or installing end-of-pipe zero liquid discharge (EOP/ZLD) wastewater treatment systems to minimize their water footprint and control their TDS.

Build Strong, Trusting Relationships

With the semiconductor industry relentlessly pursuing Moore's Law to squeeze millions more transistors onto a computer chip, the only constant in fab wastewater quality and quantity is change. As a fabs re-tool for subsequent processing nodes, the number of processing steps—now beyond 4,000 to manufacture a state-of-the-art computer chip—will only increase and wastewater discharges will only grow in volume and complexity. Furthermore, the inherent nature of the semiconductor industry—an industry that enables faster computer processing, better graphics, mobile connectivity, the Internet of Things and artificial intelligence, among others—is such that it moves at a faster pace than most other industries. This pace of re-tooling will require the WRRF to stay nimble to ensure that any upgrades or adjustments made to infrastructure are completed in time to accept and effectively treat the new fab wastewater.

Fabs may seem like a massive wastewater headache, but as the CHIPS Act incentivizes the onshoring of semiconductor manufacturing across the country, it is critical for municipalities to embrace their new challenges if they hit the chip fab lottery. In the early years after a fab is first announced, the learning curve will be very steep, almost vertical. The challenges will be significant. Over time, the semiconductor manufacturer, the WRRF and authorities having jurisdiction must develop a strong, trusting relationship to ensure mutual success. This will come in the form of regularly scheduled (at least monthly) meetings to discuss any recent incidents and to forecast, as best as possible, any future changes at either the fab campus or the WRRF, including future permit limits or new chemical species that may be discharged to the drain.

In the event of an excursion in the fab's internal wastewater treatment systems, the semiconductor manufacturer should notify the WRRF as soon as possible, even if the WRRF may not experience an impact. Similarly, if the WRRF experiences an excursion, collaboration with the chip fab campus should be the standard operating procedure. Communication and practical transparency are key for a long-term mutually beneficial relationship—without it, success will be difficult to achieve.

In the end, the work to maintain this relationship will pay off. Many communities have successfully found a happy balance between technological innovation and effective wastewater treatment and reuse (Chandler, Arizona; Albuquerque, New Mexico; Tyler, Texas; Boise, Idaho; Malta, New York; and Hillsboro, Oregon come to mind). Not only will the community have an economic engine and a constant job creator, but it will have a partner who is also invested in environmental stewardship and water sustainability.

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Photo: MicronTechnology, Inc.