

Winning the war against nitrate pollution

Angela Zhan, Logan High School, Logan, UT 84321

Chemicals are an integral part of our lives, such as sodium chloride, the salt we regularly consume every day. Nitrates, which are composed of the negative nitrate ion (NO_3^-), often combine with positive metal ions, like sodium and copper, to form different salts. With their uses varying from being key components in fertilizers and explosives to food preservation and pharmaceutical production, nitrates are recognized as a very common industrial material. Additionally, as nitrogen is an essential element for all life, nitrates that contain this element are also used as a nutrient to support cell growth in biomanufacturing.

However, when nitrates are released into the environment (air, water, and soil) as industrial waste, they can cause serious problems. Exposure to nitrates has been linked to various diseases, such as cancer and thyroid issues. For example, a recent study showed a connection between nitrate exposure and an increased risk of gastric cancer [1]. Infants are particularly susceptible to nitrates in drinking water: when the concentration of nitrates in drinking water exceeds the 10 parts per million limit set by the US Environmental Protection Agency (EPA), it can lead to methemoglobinemia, a serious and potentially fatal condition commonly known as blue-baby syndrome [2]. In addition, excessive nitrates in water can promote algal blooms, which can cause entire populations of fish to leave or even die. Some toxin-producing cyanobacteria can cause diarrhea and breathing difficulties short-term, and liver damage and cancer long-term [3]. Nitrates also affect the air quality, causing the production of toxic molecules including ammonia and ozone, which have adverse effects on both plant growth and human health [4].

I am interested in how facilities can run in an eco-friendly way and maintain a positive environmental impact, specifically by reducing nitrate production. Through the EPA's Toxics Release Inventory (TRI) Pollution Prevention (P2) Search Tool, I stumbled across TTM Technologies, a top global printed circuit board (PCB) manufacturer headquartered in Santa Ana, California. Recognizing the importance of balancing environmental and societal impact with its operations, TTM places a strong emphasis on sustainability and, specifically, the reduction of nitrate pollution. This company has a presence in multiple locations across the United States, including California, New York, Wisconsin, Virginia, and Logan, Utah: my hometown! According to its website, I noticed that the Logan facility specializes in the production of high-mix, low-volume PCBs for various industries such as medical, aerospace, defense, automotive, computing, 5G, and more.

On a Tuesday afternoon, I visited TTM Logan in the hopes of learning more about the company's efforts to reduce the use of polluting chemicals. Walking into the building, I saw a clean and organized reception area with a plaque of TTM Quality Policy on the front desk. After I explained my purpose, the receptionist kindly connected me to Mr. Glenn Ames, General Manager of TTM Logan, and he introduced me to two of his colleagues, Jackie Tolboe (EHS Manager) and Matt Schroeder (Engineering Manager). During a teleconference with Jackie and

Matt, I discussed with them about TTM's efforts to reduce nitric acid usage and asked a series of questions to gain a basic understanding of the company's commitment to sustainability and environmental responsibility.

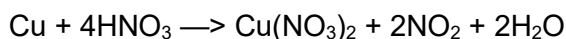
"We try to recycle and reuse chemicals at TTM. This will not only benefit our environment, but also help reduce our production costs. Every time when we reduce the use of chemicals, we get cost-saving in both chemical purchasing and disposal." Jackie told me. "We got smarter at how we use nitric acid. We improved our process control and chemical handling to significantly reduce the usage of this chemical."

"We are also evaluating the feasibility and financial viability of new technologies that can re-purify nitric acid for repeated use." Matt added.

"That's great to hear. How does the reduced use of nitric acid affect the environment and community?" I asked.

"Well, this means that less pollutants will be discharged into our environment. If you take nitrate out of the question and look at the big picture, whenever we reduce the amount of waste we process, we are reducing air pollution and water pollution, which directly benefit our environment and community." Jackie proudly said, "Where we really shine is when it comes to recycling and reclamation. We recycle and reclaim basically everything we can, such as copper, gold, silver, platinum and steel."

They told me that nitric acid (HNO₃), a highly corrosive mineral acid, is an essential chemical used in TTM's production process. The acid is used to remove extraneous plating from metal plating racks and is utilized in copper and tin stripping, resulting in the formation of corresponding nitrate salts. TTM uses a proprietary mixture of stripping solutions, which typically contain more than 10% nitric acid. The reaction of nitric acid with copper is shown below, where copper (Cu) reacts with nitric acid to produce copper nitrate, nitrogen dioxide, and water.



Through Matt and Jackie, I learned that the reaction of nitric acid with copper in TTM's production process results in the formation of copper nitrate (Cu(NO₃)₂), which can become a pollutant in the wastewater. The challenge, however, is that no known substitutes or environmentally-friendly alternative technologies are available to replace the use of nitric acid because of the nature of its chemical composition and reactivity. Despite this, TTM's team has been tirelessly working to significantly decrease the usage of nitric acid. According to TTM's TRI P2 Report submitted to the EPA, the nitric acid used in TTM's electroless plating activities is now being reused 4-7 times before disposal, leading to a considerable reduction in nitrate release. As shown in Figure 1A, in 2020, TTM used 151,189 lbs of nitric acid in its manufacturing process, of which 135,163 lbs were treated and 16,016 lbs were released. By contrast, the total use of nitric acid dropped to 130,283 lbs in 2021 (Figure 1B), a 15% decrease from the prior year. Additionally, TTM recycled 1,995 lbs of nitric acid in 2021, compared to

none in 2020. These results clearly demonstrate that TTM made great strides in reusing nitric acid and dramatically reducing its overall usage.

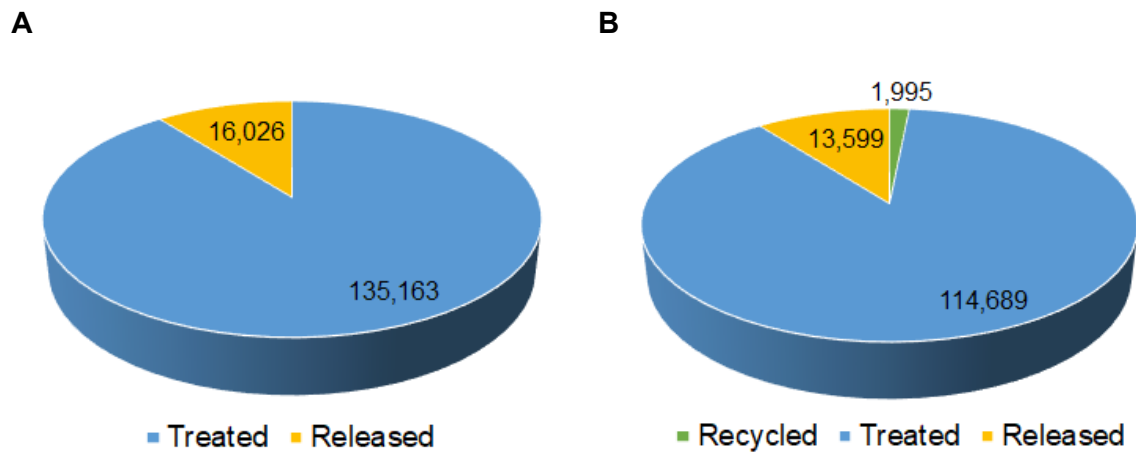


Figure 1. Use and management of nitric acid (unit: lb) at TTM in 2020 (A) and 2021 (B).

A week later, I was invited by Jackie and Matt to join them at TTM's Logan facility. The facility spans over 60,000 square feet and employs approximately 440 workers and supporting staff. During my visit, Jackie shared some impressive numbers related to TTM's efforts to reduce environmental pollution, and I was astounded by the level of detail and specificity she provided. TTM categorizes various types of waste and regularly tracks their treatment and disposal, such as hazardous waste, hazardous cupric chloride waste, non-hazardous waste, and non-hazardous ammoniacal etchant waste. Examining the amount of recycled hazardous cupric chloride waste, I discovered that TTM Logan recycled 167,340 lbs in the first quarter and 141,384 lbs in the third quarter of 2021, while these numbers increased to 233,640 and 286,500 in the corresponding quarters of 2022, reflecting a 68% rise. At the corporate level, I also saw many more encouraging numbers. As an example, TTM reduced water withdrawal, energy usage, and waste disposal per unit production by 34%, 36% and 34%, respectively, at its PCB facilities over the period of 2019-2021, affirming its unwavering commitment to sustainable and environmentally responsible practices.

After wearing the safety goggles, we proceeded to the production line and Matt introduced me to the process of PCB manufacturing, which consists of many steps, such as photoresist application, inner layer print, etch, strip, press, drill, and many more. As we walked through the different production units, I marveled at the diverse machines that were performing various precise tasks, such as soaking, washing, drying, and printing. Matt showed me the final PCBs and explained how the seemingly complex process is well-programmed. I asked him what TTM

stood for and he replied, "Time to market. Our goal is to provide one-stop manufacturing services that help our customers bring their designed products to market in a timely manner."

"What is the motivation for TTM to continuously improve the process and reduce the usage of chemicals?" I followed up.

"This is indeed a fundamental element of our corporate philosophy and I am very proud of it. We believe that it's important to take responsibility for the impact that our business has on the environment. From leadership to every employee, we're working hard to recycle and reuse the chemicals and metals in every step of our production process, which will save us and our customers costs and make a sustainable industry." Matt answered.

"We recognize the employees who came up with new ideas to reuse chemicals," Jackie added, "we have a resource recovery manager who checks on any resources that can be recycled, reclaimed or reused."

TTM's efforts in environmental protection go beyond nitrate reduction. TTM maintains a CLEAN environmental policy, including continual improvement of the environmental management system, legal compliance with applicable environmental regulations and other environmental aspect requirements, environmental protection including prevention of pollution, achieving environmental objectives, and natural resource conservation [5]. All TTM's facilities are either certified (including the Logan facility) or in the process of certification under the ISO 14001 international environmental management system standard. TTM takes community awareness seriously, disclosing its greenhouse gas emissions and water use information annually to the public through the global disclosure system CDP. The company also publishes its Corporate Social Responsibility Report every year that reviews its environmental, social and governance initiatives [5]. The fact that Jackie and Matt took the time from their busy schedule to meet and share their data with a high school student like me further reflects TTM's strong commitment to community awareness.

It is also impressive that TTM has utilized its resources to design and build its own systems for its wastewater treatment facilities. TTM treats its wastewater onsite before releasing it to the Logan Wastewater Treatment Plant for the second-round treatment. Jackie told me that TTM executed a high standard for wastewater disposal. For instance, the copper permit limit for wastewater disposal is 3.38 mg/L, as required by the City of Logan, but TTM reduces it to 1.5 mg/L before discharge, aiming to minimize the environmental impact. In fact, a key goal of TTM's operations is to reuse and recycle all manufacturing byproducts/wastes, such that no material is landfilled.

Stepping out of TTM, I had a better understanding of all its built-in procedures and comprehensive efforts in pollution prevention. I would love to see more companies take the lead in the war against not only nitrate pollution, but also other environmental challenges such as climate change and global warming, while maintaining sustainable business operations.

References

[1] Roberto Picetti, Megan Deeney, Silvia Pastorino, Mark R. Miller, Anoop Shah, David A. Leon, Alan D. Dangour, Rosemary Green. Nitrate and nitrite contamination in drinking water and cancer risk: A systematic review with meta-analysis. *Environmental Research*, **2022**, 210, 112988.

[2] <https://www.epa.gov/nutrientpollution/issue>.

[3] Feng Zhang, Jiyoung Lee, Song Liang, CK Shum. Cyanobacteria blooms and non-alcoholic liver disease: evidence from a county level ecological study in the United States. *Environmental Health*, **2015**, 14, 41.

[4] Darya Minovi and Katlyn Schmitt. Center for Progressive Reform. "Tainted tap: nitrate pollution, factory farms, and drinking water in Maryland and beyond." October **2020**.

[5] Corporate Social Responsibility Report, TTM Technologies, **2022**.