Who Cares If Our Water Is Salty?

Economic Impact of Salinity on Development/Industry

By Victoria R. Allies, TNT Technology Company and Joel Peterson, Motorola Semiconductor

FROM GOLF CLUBS TO SEMICONDUCTOR CHIPS, ANY MANUFACTURING THAT REQUIRES PROCESS AND COOLING WATER HAS TO ACCOMMODATE THE SALINITY OF THE OUR WATER. Under a City of Phoenix TDS/Cooling Tower Study project, TNT Technology identified salinity issues confronted by a wide variety of water users. This article focuses on the industrial viewpoint of salinity. The top 1000 City of Phoenix 2002 water users included 58 industrial sites, which used 20 billion gallons of water for process, cooling, landscape, and sanitary/kitchen. Yet they represent only 13% of the total 157 billion gallons used by all the city's water customers. The salt content of that water affects both operating costs and capital expenditures, especially for cooling and process.

From the 1950s, manufacturers built factories in the Valley because land was cheap and available, labor costs were low, and taxes and regulations were favorable. Despite recent losses of manufacturing jobs, those companies that stay need water to operate. Availability carries a higher risk than salinity.

Motorola Tempe site – cooling tower

RO System for process water treatment

Water for Cooling

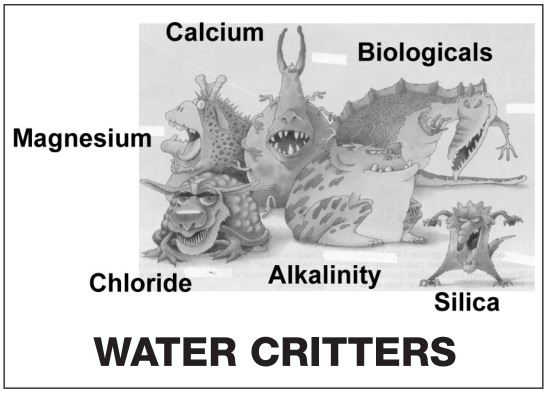
Desert heat drives the need for cooling the air for human comfort,while electronic manufacturers control air temperature and humidity in production areas to achieve the highest product quality. Water is the least expensive way to cool air and equipment because the desert dry air provides a perfect vehicle for evaporation of water. A cooling tower is a low cost piece of equipment for evaporating and cooling a circulating stream of water. Cool water is pumped from the tower to a heat exchanger, exchanging heat with a circulating refrigerant or water. The tower water absorbs heat from the circulating refrigerant or water. This chilled water or refrigerant is used to cool air. The warmer water returns to the tower, is re-cooled and the cycle repeats.

Control of water quality is essential because evaporation in the tower leaves behind salts, impurities, and solids in the circulating water. In addition, airborne impurities are regularly introduced into the open tower, intensifying the problem. Variations in water used to makeup for evaporation requires changing the amounts and types of chemicals used for water quality control, especially when calcium, alkalinity, chloride or silica concentrations vary by more than 10%. Chemical suppliers typically limit calcium hardness and alkalinity to 400 mg/l for their customers, in order to protect the equipment. In practice, most large industrial companies manage their cycles of concentration (ratio of conductivity in the bleed to the makeup water) between 2.5 to 3.5 without acid and 4.0 to 5.0 with acid.

Since this is a non-critical use of water, many manufacturers try to use treated wastewater rather than potable makeup water. The Motorola Tempe site has approximately 12,000 tons of HVAC for operating the clean rooms and providing creature comfort. Their cooling towers bleed off 60,000 gpd and makeup evaporation losses with approximately 100,000 gpd.

Water for Process

Process water is used for rinsing, cleaning, chemically treating, and generally manufacturing a product. Purification of water for process is driven by the need for consistent product quality. The more critical the product quality, the higher the degree of purity required. As semiconductor "chips" have become more complex, tiny amounts of salt in the water became sources of contamination that lower yields. This requires water purification technologies that remove all of the salt from the source water, and create Ultra Pure Water (UPW). A typical high volume semiconductor manufacturer uses 3 to 6 mgpd of water – 70% for UPW process water, 20% for cooling and air pollution abatement, and 10% for sanitary and landscape. Water isn't free – it has to be treated before it can be used in production processes and treated again before discharge to the sewer. UPW costs approximately $15.00/1000 gallons ($4887/acre-foot), including source water, treatment



and discharge costs. Water conservation has been an economic goal as use increased with wafer-size and wastewater disposal costs increased with environmental regulations. The Semiconductor Roadmap, an industry-generated document focused on technology and cost issues, shows goals of 65% reduction in UPW use and 30% reduction in cost.

Today most of semiconductor manufacturers reuse between 21 to 40% of their total water use. UPW that is used for final rinsing or only to flush equipment between cycles is reused in the process. Other UPW that requires treatment is generally reused in facility equipment such as air scrubbers or cooling towers. All water reuse technologies create wastewater that is higher in salinity than normal wastewater. The constituents in that wastewater include salts from the manufacturing processes and the wastewater treatment chemicals. This is a serious consideration for municipalities that seek to reclaim water.

The Motorola Tempe UPW system has a 130 gpm treatment train using ultrafiltration (UF) pretreatment, reverse osmosis (RO) and then electrodeionization (EDI) to produce 50 gpm of UPW. The UF membrane system has 30 gpm of wastewater containing large organics. The RO membrane system has 40 gpm of wastewater containing 95-99% of the salts in the source water as well as antiscalent and membrane cleaning chemicals. The EDI unit has 10 gpm of wastewater containing sodium chloride as well as the remaining salts from the source water. The sodium chloride comes from the brine feed to the EDI that continuously regenerates the ion exchange media. This site has two specific water conservation plans. The first will add a secondary RO system to squeeze more useable water out of the UPW system. The second will blend some of the high quality wastewater with source water for cooling tower makeup, increasing cycles in the towers. Both efforts, however, will increase the salinity of the wastewater discharged to the sewer.

Specific issues with source water quality are noted daily at this facility. RO membrane performance and operation conditions are highly dependant on consistency of source water components. As TDS increases, the volume of RO reject increases and the subsequent discharge fees. RO reject flow must increase to prevent precipitation of hardness salts and fouling of the membrane material. As TDS increases, the UPW system must increase the volume of feed water or lose capacity. To maintain capacity, capital and operating costs rise to accommodate the additional capacity requirement. Higher TDS and organic content of source water increases the frequency of RO membrane cleanings. This increases costs for cleaning, production downtime, membrane replacement due to reduced life and increased use of chemicals for cleaning, and the associated rinse-up water and wastewater. All of these items increase the overall UPW production costs.

Organics from source water are difficult to track and treat in UPW systems when the quantity and type vary with the source water. Large organic particles can be removed in pretreatment using multimedia filters (5-10 micron), UF membranes (0.10 micron or 100,000 MWC) and cartridge filters. Smaller organic particles are rejected by the RO membrane. Some organics are more resistance to UV radiation which is used to polish the UPW prior to storage and use. This effect is quantified in terms of SUVA – the Specific Ultra Violet Absorbance of the species. CAP water organics species typically have much lower SUVA values than other local source waters. This makes the CAP water organics species more difficult to destroy. Organics are devastating to UPW operations and also for chip manufacturing.

Polymer residuals in municipal drinking water can irreversibly foul RO membranes. This is a significant factor for municipal water reclaim. Some industrial customers may not be able to use reclaim water in lieu of source water for process use.

Future Implications

Manufacturing and specifically semiconductor plants have chosen Arizona sites based upon a number of factors. Water quality, in and of itself, is not a determining factor and won't be until the treatment costs exceed the targeted product cost. The feature sizes on semiconductor chips are shrinking, which means that the surface tension of water will limit its use for chemical processes and rinsing because it will no longer be able to penetrate these smaller spaces. It is anticipated that supercritical carbon dioxide could replace water or reduce use in the next 10 to 15 years.

The costs for dealing with rising salinity in wastewater discharge will be born by municipalities as they look for options for reclaim and recharge. Any discharge restrictions based on salinity will be a disincentive for water reuse within the factory and could reduce investment into technology to remove the TDS and other components. A collaborative approach would be best, so that the risk and the rewards are shared.

The desert is not going to cool down in our lifetime. And water is still the cheapest ingredient for making cool air. As salinity rises in the source water used for cooling, more chemicals will be needed to mitigate the effects of scaling, corrosion and fouling on plant equipment. In addition, the number of cooling cycles will decrease and will not meet Arizona law for water conservation.