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From zero to hero – the rise of ZLD

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Regulatory drivers are ensuring that zero liquid discharge is gaining in popularity. Capital and operating costs can still prove prohibitive, as Gord Cope discovers.

If there was ever a Holy Grail of water recovery and reuse in an industrial plant, then it is undoubtedly zero liquid discharge, or ZLD. While it may be difficult and expensive to achieve, zero liquid discharge is easy to define.

“A ZLD system means that no liquid waste leaves the boundary of the facility,” says Keith Minnich, Veolia’s vice president of water solutions and technologies. “Technically, that could mean you have a big pond inside the fence, but the term usually refers to a mechanical system of an evaporator and a crystallizer.”

There are thousands of evaporator/ crystallizer thermal systems in use around the world, serving a wide variety of sectors. Chemical plants use them to make chloride for feedstock in the plastics industry. The food and beverage industry produces powdered coffee and milk. But relatively few of these systems (a total of just over 100 worldwide), are designed purely as ZLD systems, in which the purpose is to recover and reuse as much water as possible.

Although dozens of regional companies supply various components for evaporation and crystallization, the ZLD niche is dominated by three major players: Aquatech, GE Power and Water, and HPD, a subsidiary of Veolia. “HPD is the largest evaporation and crystallization company in the world,” says Minnich. “We have close to 700 systems in many different sectors: pulp and paper, salt, chemical processing, oil and gas, biofuels, and power generation. Many of these installations are not ZLD systems; they are part of a system used to produce an industrial product.” In all, total capital investment in ZLD systems around the world is estimated to be between $100-200 million per year.

Most industrial processes create a wastewater stream. This can be bleed from boilers, blowdown from cooling towers, or saline water from crude oil extraction. Reverse osmosis and other membrane technologies can cut the stream by 80% or more, but a facility inevitably still ends up with a significant flow of concentrated liquid waste.

Generally speaking, the smaller the volume, the easier it is to dispose of. “In conventional processes, you typically get sludge with 30 to 40% solids, whereas in a ZLD system the solids content ranges between 85 and 95%, thus providing a much lower volume and dryer sludge,” says Anant Upadhyaya, senior vice president of corporate growth at Aquatech, which entered the ZLD space in 2000 through its acquisition of Aqua-Chem. “Why not minimize the wastewater by recovering and reusing water, which is essentially what the ZLD process does?”

The ZLD process creates solid waste using two devices – evaporators and crystallizers. Evaporators, which can concentrate brines up to 250,000 ppm TDS, are designed to be extremely energyefficient by using mechanical vapour recompression, or VPR. “If you were to simply boil water on a stove, it would take 1,000 Btus to boil one pound of water,” says Minnich. “But if you use VPR, it only takes 30 Btus.” In the VPR evaporator process, water is heated until it boils at 100°C. The vapour goes into a centrifugal compressor which compresses it slightly, making the temperature rise. The boiling takes place on a thin-film heat transfer surface, where steam condenses on one side and water boils on the other side.

When the brine concentration exceeds 250,000 ppm TDS, it is pumped under high pressure from the evaporator to a forced circulation crystallizer. The brine is released into a vessel where the pressure falls, the remaining water boils off and the salts crystallize. This salt is still slightly damp, but conforms to EPA solid disposal standards. The salt cake, which is a fraction of the original waste stream, is then disposed of in landfill.

There are several drivers for the adoption of ZLD. “Water is a resource that is getting scarce in many geographic locations,” says Upadhyaya. “In many locations in the US, the Middle East, Africa, India and China, less than 5% of wastewater is presently recovered. With water becoming so scarce, the very first thing that comes to mind is: why are we wasting so much? The first inclination is to recover and recycle.”

A second motivator is the growing social responsibility of recycling and reuse. “The EU has many countries with limited resources,” says Upadhyaya. “Those circumstances have led to a compulsion toward minimum wastage, maximum reuse. Twenty years ago, there was little of that in North America, but now we recycle bottles, newspapers and plastics. Society deems it worthwhile to do so, and technologies have evolved to make economic recycling possible.”

A third driver is economics. As potable water becomes scarcer in many jurisdictions, its price rises. In addition, as regulations on the discharge of waste fluids into open waterways become more stringent, treatment costs rise. Customers look at the potential for savings, comparing the cost of ZLD to the cost of fresh water and the savings on sludge disposal. Regulation represents the biggest incentive by far. “Nobody puts in a ZLD unless they have to, because it’s very expensive,” says Tim Cornish, marketing manager for HPD. “It’s driven by discharge regulations.”

Don’t pass the salt

It was US federal regulatory pressure that gave birth to the ZLD sector. “Back in the 1970s, they were having a salinity problem in the Colorado River,” says Minnich.

“As a result, regulations were created prohibiting discharge of cooling tower blowdown into the river. Evaporation-based technology was developed to recover the water and concentrate the salt. The distillate evaporated and was returned to the power plant, and the highly concentrated brine went to a crystallizer where it was processed into salt cake. The systems would handle 500-2,000 GPM. There were dozens built.”

Since then, many state jurisdictions have added salt discharge restrictions to their own statutes. “In places like Colorado, Arizona and California, they are regulating discharge to the point where it’s almost ZLD,” says Cornish.

Increasingly, the decision to install ZLD is made for a combination of reasons. Italy derives a significant amount of electricity from coal, and in addition to boiler blowdown, coal-fired power plants must also deal with liquid waste generated from flue gas scrubbers. “When plants burn coal, flue gases are discharged into the atmosphere,” says Upadhyaya. “Years ago, we realized that the gases were very acidic, toxic and caused damage. Regulations were then mandated that the flue gases be scrubbed, and contaminants transferred from vapour to liquid phase. This produced a high amount of wastewater requiring complex treatment.” Enel, a large power utility in Italy, wanted to address this issue. “Their vision was to be compliant with the ideology of environmental conservation. They wanted to set an example of environmental stewardship and social responsibility.”

Enel had other motives, too. Water in some plant locations was scarce, and opposition vocal. “When you include ZLD in a greenfield application, you obviate the need for the permitting of liquid disposal,” says Upadhyaya. “This puts you on the fast track for regulatory approval in sensitive environment zones. In the end, they decided having the ZLD approach was worth it to them.”

Aquatech supplied equipment to five of Enel’s coal-fired facilities. “Each plant has a custom-designed treatment train,” says Upadhyaya. “In one of the plants, the main equipment consisted of two de-calcifiers and two brine concentrators. They handled 1,744m3/d, recovering 1,555m3/d, which left less than 200m3/d of solids.”

Zero has its minuses

The main disadvantage to ZLD is its capital cost. A large industrial facility with a traditional wastewater treatment system costing approximately $20 million can recover and reuse up to 80% of its liquid waste streams. The 1,000 GPM (3.8m3/ min) evaporator and crystallizer system necessary to capture the last 20% can, however, double that cost.

A second factor is the operating budget. Although ZLD systems are built from corrosion-resistant titanium and highnickel stainless steel and don’t require a lot of repair, energy costs are high. “Evaporators and crystallizers use a lot of electricity,” says Minnich. “A desalination plant might use 2-4 kWh/m3, but these systems use 20-40 kWh/m3.”

As a result, very few municipalities – which generally have high wastewater flows with low TDS concentrations – use ZLD unless forced to by unusual circumstances. “There are inland municipal desalination plants,” says Minnich. “They use groundwater with 2,500-15,000 ppm TDS to produce drinking water. These plants produce a waste brine stream with approximately 80,000 ppm dissolved solids. Environmentally acceptable brine disposal can be a problem. Not only that, there is still a lot of water left in the brine. ZLD using evaporation and crystallization is expensive, and municipalities don’t want to pay the cost. VWS has a process called Zero Discharge Desalination (ZDD), which can recover 97% of the water fed to an inland desalination plant, compared to the typical 80%. This technology uses electrodialysis and is suitable for municipal applications.”

Even when circumstances such as regulation and scarcity oblige industry to adopt ZLD, great care is taken to limit its role. According to Siemens Water Technologies, which recently installed a ZLD system at an automotive plant in Mexico, the first step is a water audit to identify the sources and types of wastewater generated in a facility in terms of flow and TDS content.

Some sources generate high concentrations of organic compounds, salts, metals and suspended solids. Others are relatively clean, such as condensate and stormwater, and require little cleaning. Secondly, the audit identifies points where fresh water and make-up water are used, and in what quantities and qualities. Some applications do not require water to be treated to a potable standard, for example fire water, utility water, process water and cooling water. By matching appropriate water requirements and waste streams, the amount of wastewater that ultimately enters the ZLD system can be greatly diminished.

In the case of a typical refinery, Siemens has identified several processes in which large quantities of wastewater could be safely reused with a minimum of treatment. Large volumes of water, for instance, are used to strip sulphur from gasoline and diesel products. This sour water can be put to a second valuable use – removing salts from crude as it enters the refinery – with little or no treatment. Even though such techniques can dramatically reduce wastewater treatment requirements, the remaining waste streams are a complex mix of organic and inorganic materials that make 100% reuse of water restrictively expensive, with the result that no refinery has yet advanced to a true ZLD system.

New markets

Other areas of the oil and gas industry are making significant strides towards ZLD, however. For several decades, heavy oil production in regions such as California and Venezuela has relied on the injection of steam to recover the viscous crude.

"Up until about 12 years ago, water recovered from heavy oil production was treated with warm lime softening and weak acid cation ion exchange, then fed into once-through steam generators (OTSGs) to produce 80% steam and 20% water for downhole injection into the oil wells," says Bill Heins, general manager of thermal products and ZLD for GE Water & Process Technologies. GE entered the ZLD market in 2005 through its purchase of Ionics, which itself had acquired ZLD specialist Resources Conservation Company (RCC) back in 1993.

About a decade ago, oilsands operators in northeast Alberta began developing a thermal technique known as steamassisted gravity drainage (SAGD) to recover bitumen that was buried too deep for open pit mines. With SAGD, two horizontal wells are drilled, one above the other. Steam is then injected into the upper well, where it heats up the surrounding bitumen, which then sinks to the lower well and is brought to the surface by pumps.

"For SAGD, you need 100% steam," says Heins. "They modified the old systems with vapour/liquid separators to get 100% steam, but we saw a lot simpler and more cost-effective way. Why not take produced water and run it through an evaporator to create water quality good enough for a standard drum boiler that would make 100% steam?"

Clients didn't warm to the idea initially, and there was concern that evaporators use a lot of electricity, recalls Heins. "But we did a lot of R&D to show that it was technically and economically viable. At the end of the day, the client could save approximately 10% on capital costs and 6% on operating costs while implementing a process that was more reliable and simpler to operate. Produced water evaporator systems are now the industry baseline for greenfield facilities, and we have 10 installs in the heavy oil recovery market."

Several other sectors are opening up. "The mining industry has great potential for ZLD," says Heins. "We recently installed a large mine drainage wastewater ZLD that reuses the water and creates a saleable salt product that can be used to de-ice roads. We are taking waste and turning it into a useful product."

"Royal Dutch Shell is building an $18 billion gas to liquid (GTL) plant in Qatar," adds Veolia's Minnich. "Shell and the government decided to go with ZLD due to environmental concerns and water scarcity in the area. VWS is building a large-scale turnkey wastewater treatment system that will treat 33,000m3/d of plant effluents. It uses physical chemical-membrane, biological and thermal ZLD systems to recover all of the water for reuse in the plant. It produces a dry salt that is disposed of on site."

POET, the world's largest producer of ethanol, recently installed a ZLD system in its 34 million gallons per year (353m3/d) Bingham Lake, Minnesota, facility. The production of one gallon of ethanol normally uses about 3.5 gallons (13.25 litres) of water. POET had already met all state discharge regulations, but wanted to eliminate discharge completely. Their new system recycles about 20 million GPY (207m3/d) of treated wastewater that was formerly discharged into the drought-prone agricultural district.

ZLD also has great potential in the development of shale gas. "Shale gas recovery uses a lot of water to fracture the rock," says GE's Heins. "The water comes back up with up to 15,000 ppm TDS. Traditionally, they take that water and haul it far away for disposal. That's very expensive. We're looking at onsite treatment and reuse in fracturing to minimize or eliminate the need to haul it. We are poised to deliver our first system to the field. There are dozens of shale basins in North America, and regulations are pushing toward treating the fracture water."

R&D sums

The fact that operating costs are high naturally means that R&D in the ZLD arena has been directed towards finding alternatives to energy-intensive evaporator/ crystallizer systems. "There have been attempts to use reverse osmosis-based technology for power plant ZLD systems, but they just haven't been very effective," says Minnich. "The membranes foul faster than they are supposed to."

Progress has been made in lowering capital costs, however. "When we started out seven years ago, we had a total installed cost factor of 5.0," says Heins. "That meant that a $10 million unit cost $50 million after installation. Now, we're on our fourth generation modular design, and we've reduced the total installed cost factor down to 1.8-2.0. A $10 million unit now costs $18-$20 million total installed. That makes produced water evaporation a lot more economically viable."

Although the recession has had a negative impact on many sectors of the economy, ZLD has not slowed dramatically. In fact, industry analysts predict a cumulative annual growth rate for recovery/ reuse systems in excess of 200% over the next decade, of which a significant portion could be accounted for by ZLD capacity. "The economic and regulatory climate is such that ZLD or near zero discharge is going to continue to grow rapidly," says Cornish. "We see great potential."

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