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Technology Brief

ACHIEVING ZERO LIQUID DISCHARGE FOR INDUSTRIAL WASTEWATER WITH GRADIANT'S CARRIER GAS EXTRACTION

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I. INTRODUCTION

Achieving minimum liquid discharge (MLD) and zero liquid discharge (ZLD) is crucial for industries that generate complex wastewaters. MLD/ZLD allows for the recovery of more water and resources while discharging less waste, leading to more sustainable practices, and achieving regulatory compliance. However, accomplishing MLD/ZLD is challenging and has been attempted by many industries. This white paper will discuss a novel process for achieving MLD/ZLD in various industrial applications, including pharmaceuticals, chemical manufacturing, and textiles. It will also explore why achieving MLD/ZLD is difficult, why other methods fail, and how Carrier Gas Extraction (CGE) excels in achieving MLD/ZLD while being cost-effective for customers.

II. Why Do Industries Want to Achieve MLD/ZLD?

Industries are often driven to achieve MLD/ZLD for sustainability goals, regulatory compliance, or business growth. Reducing waste volume through MLD/ZLD would significantly decrease costs associated with waste management and disposal. Achieving these results involves minimizing wastewater discharge while maximizing water recovery.

In Tamil Nadu, India, many Common Effluent Treatment Plants (CETP) cannot accept additional effluent from customers, because they are already at over 90% of their permitted quantity. In an industrial area like Tirupur, that produces the world's textiles, companies cannot expand their businesses because they cannot produce more waste. So MLD is a must.

In Singapore, waste management companies can no longer accept wastewater from certain industrial clients because their wastes are getting more complicated, with increasing loads of organics and contaminants that disrupt the balance in their treatment plant. This can cause the waste management companies to exceed their ever-tightening discharge limits.

In Texas, while waste management companies are willing to accept waste from their oil & gas clients, the waste facilities are hundreds of kilometers away. Hauling that much waste over long distances is cost-prohibitive.

MLD/ZLD can be applied to a range of industrial applications, including pharmaceuticals, chemical manufacturing, and textiles, making it a versatile solution. However, an onsite MLD/ZLD process is often a daunting challenge due to the complexities of operating such a system. This leads to high manpower requirements and operational and capital expenditures.

III. Why Do Many Fail to Achieve MLD/ZLD?

Many industries have attempted to achieve MLD/ZLD with little success. The main reason is the complicated and varying nature of wastewater. Most membranes foul very quickly under the demanding conditions required for MLD. If they manage to process the water, they generally have much shorter lifespans or break from the stress, resulting in equipment failure.

Additionally, fouling and scaling issues can lead to significant maintenance costs, making the process uneconomical. These factors make it difficult for industries to achieve MLD/ZLD, leading to a search for alternative methods.

Thermal systems such as Multi-Effect Evaporators (MEE) or Mechanical Vapor Re-compressors (MVR) are considered more robust technologies, but they are not impervious to scaling. In tough waters, a thermal system may run about 15 to 30 days before capacity or efficiency fall due to scaling. To restore system operations, a clean-in-place (CIP) will be required, typically resulting in 5 days downtime. Operating a system in this manner can be troubling for end users as they prefer to adopt continuous, automated, and consistent systems.

Figure 1: Equipment fouling & scaling

IV. The Solution: Carrier Gas Extraction (CGE)

Gradiant's CGE is a thermal desalination technology that mimics the rain cycle. Invented at MIT in 2008, CGE uses a carrier gas, commonly air, to evaporate brine into fresh water. The carrier gas moves water vapor from the humidifier and leaves behind the contaminants and salts. The vapor is transported to the dehumidifier where it condenses and produces near-distillate quality water. This act of moving fresh water from one column to another allows brine to concentrate up to its saturation limit in the humidifier and when coupled with a dryer, a novel solution for MLD/ZLD is contrived.

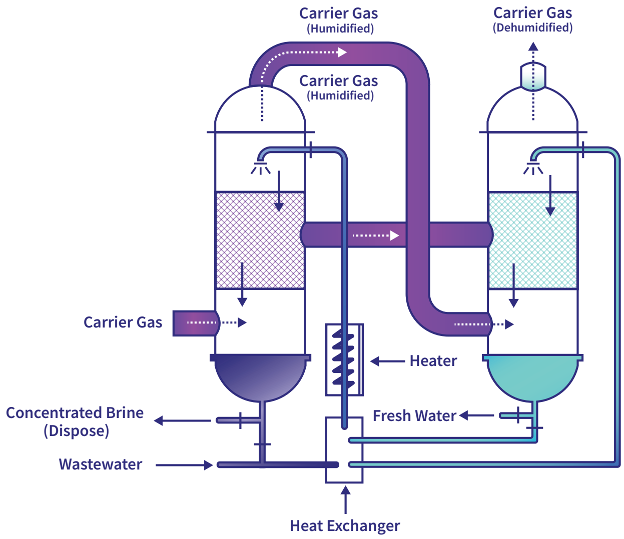

Figure 2: Schematic Diagram of CGE

V. How CGE Works

To achieve ideal evaporation, brine is being pumped through a heat exchanger where it heats to a temperature just below its boiling point and re-enters the humidifier at the top. Air is introduced just above the sump level in the humidifier and flows in a counter direction to the brine flow. Coupled with the use of packing material, this increases brine to air contact, thereby improving the efficiency of CGE.

VI. Why CGE is Different

Unlike membrane and other thermal technologies, CGE is robust against scaling and fouling, with ease of maintenance and higher uptimes. This is predominantly because CGE decouples heat and mass transfer surfaces. Most scaling and fouling occur on mass transfer surfaces and in the case of CGE, the inexpensive plastic packing. Thermal systems start to drop in performance once there is a 0.1 mm of scale forming, because their heat exchangers are scaling. CGE can handle 10x to 100x of that amount of scaling on its packing.

Figure 3: Fouling on Gradiant's CGE Packing Media

Gradiant's CGE heat exchangers are used to bring the brine to an ideal temperature. Since there is no evaporation, the surfaces are kept clean and maintain a high thermal efficiency. That leads to significantly smaller heat exchangers, which makes it cost effective to have provisions of additional heat exchangers for maximum uptime of the process.

Besides being robust against scaling and fouling, CGE can leverage waste heat recovery to lower operational expenditure. Past CGE projects have seen heat being recovered from sources such as flue gases and dryers.

VII. Key CGE Applications

CGE has proven successful in a range of industrial applications, including pharmaceuticals, chemical manufacturing, and textiles. In the pharmaceutical industry, CGE can be used to recover valuable solvents, reducing the amount of wastewater discharged. CGE has also been applied to the concentration of brine streams in chemical manufacturing, reducing the volume of waste and increasing water recovery rates. In the textile industry, CGE has been used to remove salt and dye from wastewater, thereby reducing environmental impact.

VIII. Client Success: Minimum Liquid Discharge in an Extremely Limited Footprint

A global pharmaceutical and biotech company's antibiotics manufacturing plant in Singapore produced wastewaters containing organic solvents and unrecovered amoxicillin products, which were restricting overall manufacturing yields and waste disposal. The primary challenge was to identify a compact process solution that could sustainably treat high COD, TDS, and Chlorides feedwater. All within an extremely challenging limited footprint available at the brownfield site. The client had been unsuccessful sourcing a credible solution.

The Solution

Gradiant engineered and delivered a custom designed CGE system. The dedicated project delivery team deployed bench-scale lab testing to demonstrate proof of concept and the proven cost advantages of using CGE. Quantified results were complimented by in-house unique design innovation for the design-build project phase of this MLD facility – creating savings of 35% in CAPEX and 50% in OPEX relative to competitors.

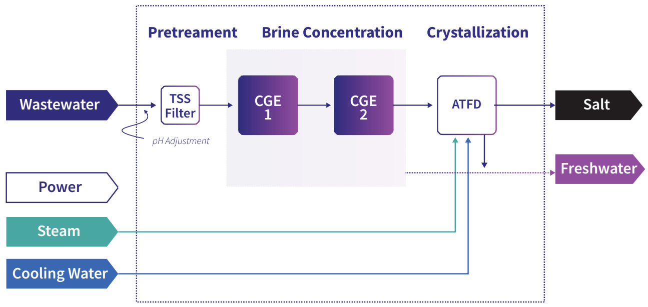

Figure 4: CGE Process Flow Diagram

In an unprecedented deployment, Gradiant's engineers designed the CGE technology as two 32-meter towers to accommodate the existing facility's very limited footprint. The CGE technology has been proven to help other clients achieve 20x brine concentration, and when combined with ATFD, reduce overall disposal volumes by over 98%, while lowering effluent COD and TDS concentrations. The ZLD process scheme feeds the remaining concentrated brine to an Agitated Thin Film Dryer to achieve >80% purity solids cake.

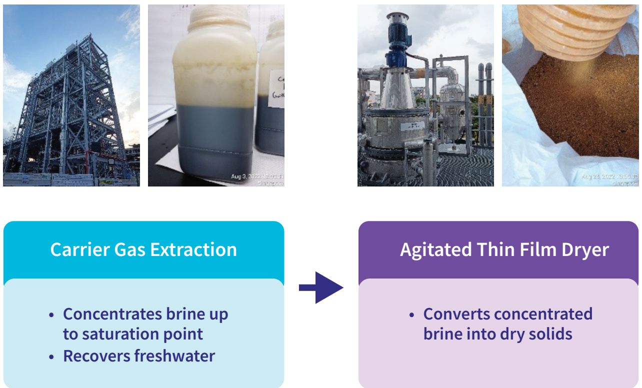

Figure 5: CGE to ATFD Transfer

The Benefits

Gradiant's solution proved to be superior on a technical and economic basis to address brine concentration and minimum liquid discharge – overall disposal volumes were reduced by over 98%, while lowering effluent COD and TDS concentrations. By implementing the solution, the client could focus on providing the world supply of amoxicillin and other key medicines. Exceeding expectation by providing savings of up to 35% and 50% in CAPEX and OPEX compared to competitor technologies.

Following the project's successful deployment, Gradiant is creating opportunities for other pharmaceutical brand owners to bring sustainability into their operations and solve their unique manufacturing challenges - to ensure their focus remains on producing lifesaving medicines and cures for the global population.

Overall, the CGE process provided several key benefits, including:

- Lower operating and capital expenditures due to reduced energy requirements and lower maintenance costs
- Higher water recovery rates, leading to more sustainable practices and reduced environmental impact
- Longer equipment lifespan due to reduced fouling and scaling issues

Figure 6: Carrier Gas Extraction System in Singapore

IX. Conclusion

Achieving MLD/ZLD is crucial for industries that generate complex wastewaters. However, traditional membrane processes can be prohibitive due to equipment requirements, fouling, and scaling issues. Gradiant's CGE process provides a novel solution to these challenges, allowing many industries to treat their water more sustainably with minimal liquid discharge, while keeping energy requirements to a minimum.

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Learn More at www.gradiant.com/technologies/carrier-gas-extraction

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