A Zero Liquid Discharge in Chemical Industry: A Review

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1. Abstract

Treatment of wastewater is an important issue because there is limited source of drinking water. This review is the approach to Zero Liquid Discharge (ZLD) technology. ZLD is an ideal situation of complete closed loop cycle, where discharge of any liquid effluent is eliminated.The objective of a very much planned Zero Liquid Discharge (ZLD) framework is to limit the volume of fluid waste that requires treatment, while additionally delivering a spotless stream reasonable for use somewhere else in the plant forms. A typical ZLD approach is to dissipate the wastewater and afterward discard it as a liquid brine solution. The evaporated water is recuperated and reused while the salt water is consistently concentrated to a higher solids fixation. Applicability and feasibility study of different techniques like: ultra-filtration, reverse osmosis, different type of evaporator etc. would also be done in later stage of project. Based on all studies and results of experiments, methodology would be suggested to achieve ZLD in given industry.The advantage of the process are also discussed.

Key Words: Zero Liquid Discharge (ZLD), Evaporator, Reverse osmosis (RO), Wastewater(WW)

2. Introduction

The exact components of a ZLD treatment system will largely depend on (1.) the volume of dissolved material present in the waste, (2.) the system's required flow rate, and (3.) what specific contaminants are present. But in general, a basic ZLD treatment system typically includes some type of:

- **Clarifier and/or Reactor** to precipitate out metals, hardness, and silica
- **Chemical Feed** to help facilitate the precipitation, flocculation, or coagulation of any metals and suspended solids
- **Filter Press** to concentrate secondary solid waste after pretreatment or alongside an evaporator
- **Ultrafiltration (UF)** to remove all the leftover trace amounts of suspended solids and prevent fouling, scaling, and/or corrosion down the line of treatment
- **Reverse osmosis (RO)** to remove the bulk of dissolved solids from the water stream in the primary phases of concentration.
- **Brine concentrators** to further concentrate the reject RO stream or reject from electrodialysis to further reduce waste volume.
- **Evaporator** for vaporizing access water in the final phases of waste concentration before crystallizer.
- **Crystallizer** to boil off any remaining liquid, leaving you with a dry, solid cake for disposal.

3. Working of ZLD treatment system

A typical ZLD treatment facility process will usually include the following steps:

3.1 Pretreatment and conditioning

Pretreatment is used to remove simple things from the wastewater stream that can be filtered or precipitated out, conditioning the water and reducing the suspended solids and materials that would otherwise scale and/or foul following treatment steps.

Typically this treatment block consists of clarifier and a reactor to precipitate out metals, hardness, and silica. This step requires the addition of caustic soda or lime to help with coagulation, a process where various chemicals are added to a reaction tank to remove the bulk suspended solids and other various contaminants. This process starts off with an assortment of mixing reactors, that add chemicals to take out all the finer particles in the water by combining them into heavier particles that settle out. The most widely used coagulates are aluminum-based such as alum and polyaluminum chloride.

Sometimes a slight pH adjustment will help coagulate the particles, as well.

When coagulation is complete, the water enters a flocculation chamber where the coagulated particles are slowly stirred together with long-chain polymers (charged molecules that grab all the colloidal and coagulated particles and pull them together), creating visible, settleable particles that resemble snowflakes.

The gravity settler (or sedimentation part of the ZLD treatment process) is typically a large circular device where flocculated material and water flow into the chamber and circulate from the center out. In a very slow settling process, the water rises to the top and overflows at the perimeter of the clarifier, allowing the solids to settle down to the bottom of the clarifier into a sludge blanket. The solids are then raked to the center of the clarifier into a cylindrical tube where a slow mixing takes place and the sludge is pumped out of the bottom into a sludge-handling or dewatering operation. The settlers can also be designed using a plate pack for smaller footprint.

Depending on the material in the feed, additional reactors or chemistry may be required for the reduction of metals or silica. Careful consideration must be given to the pretreatment step for a successful ZLD system.

Ultrafiltration (UF) can also be used after the clarifiers instead of the gravity sand filter, or it can replace entire clarification process altogether. Membranes have become the newest technology for treatment, pumping water directly from the wastewater source through the UF (post-chlorination) and eliminating the entire clarifier/filtration train.

Out of this process comes a liquid that is then filter-pressed into a solid, resulting in a solution much lower in suspended solids and without the ability to scale up concentration treatment.

3.2 Phase-one concentration

Concentrating in the earlier stages of ZLD is usually done with membranes like reverse osmosis (RO), brine concentrators, or electrodialysis.

The **RO train** will capture the majority of dissolved solids that flow through the process, it's important to flow only pretreated water through the RO system.

Brine concentrators, on the other hand, are also used to remove dissolved solid waste but they are usually able to handle brine with a much higher salt content than RO. They are pretty efficient for turning out a reduced-volume waste.

Electrodialysis can also be used at this part of the ZLD treatment system. It's a membrane process that uses positively or negatively charged ions to allow charged particles to flow through a semipermeable membrane and can be used in stages to concentrate the brine. It is **often used in conjunction with RO** to yield extremely high recovery rates.

Combined, these technologies take this stream and concentrate it down to a high salinity while pulling out up to 60–80% of the water.

3.3 Evaporation/crystallization

After the concentration step is complete, the next step is generating a solid, which is done through **thermal processes or evaporation**, where you evaporate all the water off, collect it, and reuse it. Adding acid at this point will help to neutralize the solution so, when heating it, you can avoid scaling and harming the heat exchangers. **De-aeration** is often used at this phase to release dissolved oxygen, carbon dioxide, and other non-condensible gases.

The leftover waste then goes from an evaporator to a **crystallizer**, which continues to boil off all the water until all the impurities in the water crystallize and are filtered out as a solid.

3.4 Recycled water distribution/solid waste treatment

If the **treated water** is being reused in an industrial process, it's typically pumped into a holding tank where it can be used based on the demands of the facility. The ZLD treatment system should have purified the water enough to be reused safely in your process.

The **solid waste**, at this point, will enter a dewatering process that takes all the water out of the sludge with filter or belt presses, yielding a solid cake. The sludge is put onto the press and runs between two belts that squeeze the water out, and the sludge is then put into a big hopper that goes to either a landfill or a place that reuses it. The water from this process is also typically reused.

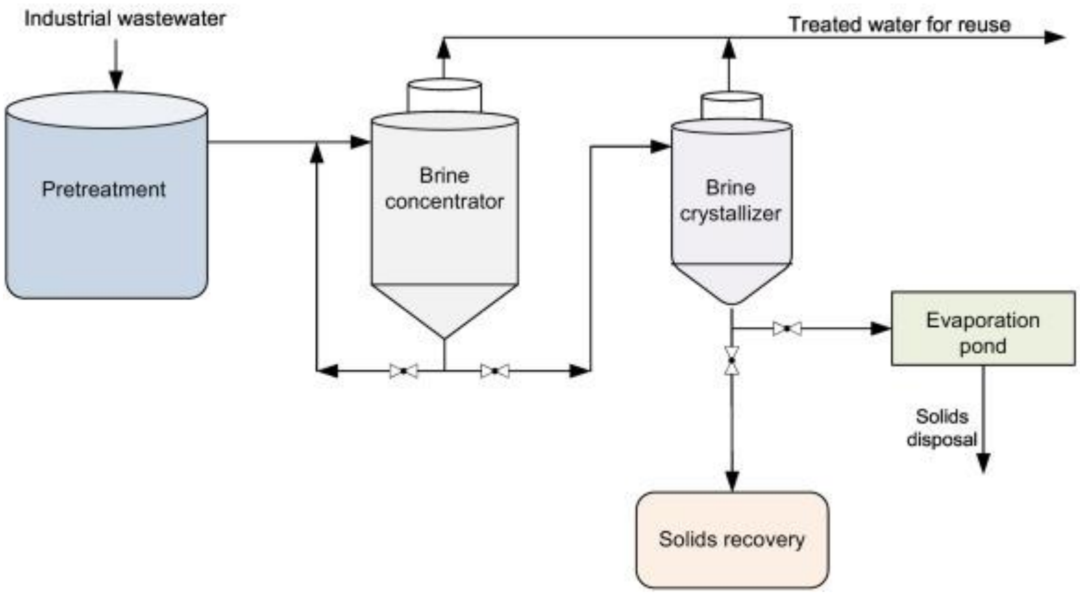

Fig 1: Zero Liquid Discharge

4. Advantages of ZLD:

- Water Conservation
- ZLD systems employ the most advanced wastewater treatment technologies to purify and recycle virtually all of the wastewater produced.
- Reduces the wastewater discharge i.e. reduces water pollution
- Preferred option for industry where disposal of effluent is major bottleneck
- Prevents exploitation of hydraulic capacity of disposal system
- Separation of salts / residual solvents improve efficiency of ETP and CETP
- Separated solids valuable by-product which helps in reducing the payback period
- Mixed solvent separated in stripper can be reused or used as Co-processing
- Ease in getting environmental permissions
- More focus on production/ business rather than tracking after regulatory authorities
- Reduction in water demand from the Industry frees up water for Agriculture and Domestic demands.

5. Conclusion

The goal of a well-designed Zero Liquid Discharge (ZLD) system is to minimize the volume of liquid waste that requires treatment, while also producing a clean stream suitable for use elsewhere in the plant processes. A common ZLD approach is to concentrate (evaporate) the wastewater and then dispose of it as a liquid brine, or further crystallize the brine to a solid. The evaporated water is recovered and recycled while the brine is continually concentrated to a higher solids concentration. The effluents are desired to be treated to meet the regulatory limits. Basically the levels of COD and total suspended solids are to be reduced to acceptable values given by the Pollution Control Board and pH to neutral. Treated water can be reused for activities such as gardening, boiler feed, etc. and the removed waste is classified as organic and inorganic waste and treated accordingly. Other by-products during treatment, such as hydro carbons, lead etc. are used or sold according to the need of the industry. Other than the necessity of meeting the pollution control board norms, treating the wastewater helps in reusing tons of water within the industry and not wasting a single drop and hence it is called Zero Liquid Discharge. The role of engineer in Zero Liquid Discharge plant is to optimize operating cost, to increase steam economy and to increase solvent recovery.

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