International Journal of Membrane Science and Technology, 2023, Vol. 10, No. 2, pp 2743-2751

Comparitive Study of Two ZLD Treatment Plants

D. Devi Sahithya [1*], M. V. V. Chandana Lakshmi [2]

[1] Research Scholar, Department of Chemical Engineering, AU College of Engineering, Andhra University, Visakhapatnam, Andhra Pradesh, India. devisahithyaduddukuri@gmail.com

[2] Professor, Department of Chemical Engineering, AU College of Engineering, Andhra University, Visakhapatnam, Andhra Pradesh, India

Abstract: Due to the increased demand for water over the past ten years, the recovery and recycling of wastewater has become a major trend. An ambitious wastewater management technique known as ZLD aims to completely remove all liquid wastes from leaving the plant or facility boundaries, with the bulk of water being recovered for reuse. This system uses cutting-edge scientific water treatment procedures to reduce the amount of liquid waste produced at the conclusion of your industrial process to zero, which is both effective and environmentally friendly. It is a procedure that benefits industrial, municipal and environmental groups because no effluent or discharge is generated. The treatment of industrial wastewater from two different companies was examined in this study over an 8-month period utilizing two ZLD treatment plants. Two ZLD processes were identical, but they were differed at two steps where batch evaporator and rotary kiln replaced each other with MEE and ATFD. In order to assess which process is reliable, two ZLD treatment plants were evaluated in terms of quantity, time, steam consumption, power consumption, and operational cost.

1. INTRODUCTION

Environmental and human health have been put at risk by the discharge of industrial effluents. Reclamation of industrial effluents is gaining attention from the academic and industrial communities in order to create a win-win situation of water conservation and pollution control, with ZLD technologies that support this viewpoint rising (Liang Yinglin *et al.,* 2021). This system uses cutting-edge scientific water treatment procedures to reduce the amount of liquid waste produced at the conclusion of your industrial process to zero, which is both effective and environmentally friendly. ZLD is the answer for obtaining the rigorous environmental discharge guidelines and offering effective treatment at the lowest life-cycle cost achievable. It is a procedure that benefits industrial, municipal and environmental groups because no effluent or discharge is generated (Nibe R. L *et al.,* 2022).

Due to the increased demand for water over the past ten years, the recovery and recycling of wastewater has become a major trend (Hovel Thekla, 2021). An ambitious wastewater management technique known as ZLD aims to completely remove all liquid wastes from leaving the plant or facility boundaries, with the bulk of water being recovered for reuse (Tong Tiezheng and Menachem Elimelech, 2016).

Some of the potential utilizes for recycled treated water were: in cooling towers, especially big scale industries, suitable for use in gardening to water plants and lawns, in toilet flush, as cleaning medium in a water scrubber, for preparing lime slurry for ETP, different industrial washing operations and used as boiler feed.

2. DESCRIPTION OF ZLD TREATMENT PLANTS

In the present study, treatment of industrial wastewater from two different fertilizer industries was investigated for 8-month period using two ZLD treatment plants namely P-1and P-2. The main sources of effluent generation from the plants were segregated into two types viz. process effluents (organic and inorganic in nature) and non-process effluents (from boiler blowdowns and cooling towers).

2.1 P-1 Description

The larger particulates and oil floating on a liquid surface were first removed from the process effluent using bar screens and oil skimmers before being delivered to neutralization tank - 1 where a neutralizing agent was applied before being sent to the primary clarifier - 1. In primary clarifier - 1 most of the solids settle to the bottom and then this effluent is fed into stripper to reduce the COD content and the stripped liquid (VOC) sent to authorized cement plants for co-incineration. After stripping, process effluents were sent to the batch evaporator where the high TDS effluents were concentrated. The batch evaporator condensate was collected for further processing in biological treatment plant and the concentrate was sent to rotary kiln in which most of the solids were dried and disposed to landfilling. The non-process effluents and batch evaporator condensate were sent to the neutralization tank-2 for biological treatment. Neutralizing chemical was added into the neutralization tank-2 and the effluent was fed to primary clarifier - 2. In primary clarifier - 2 most of the solids settle to the bottom and the overflow was fed into the aeration tank. In aeration tank, aeration provides oxygen to bacteria for treating and stabilizing the wastewater. Oxygen was needed by the bacteria to allow biodegradation to occur. The supplied oxygen was utilized by bacteria in the wastewater to break down the organic matter containing carbon to form carbon dioxide and water. The over flow from the aeration tank was sent to secondary clarifier. A portion of the settled sludge was recirculated to aeration tank for maintaining the required concentration of mixed liquor suspended solids. In secondary clarifier, suspended solids settle down and its overflow was sent to RO plant. RO plant works by removing impurities from contaminated water. It does this through the process of pressure, forcing the contaminated solution through membranes. The RO reject water was sent to further treatment in batch evaporator and the RO permeate was the treated effluent which meets the standards prescribed by CPCB and can be used in cooling towers, washing operations, boiler feed etc.

2.2 P-2 Description

The process effluent treatment from the bar screen to the stripper was same as the P-1 process. Process effluent was sent to MEE after stripping, where high TDS effluent was concentrated and less steam was used compared to the batch evaporator in the P-1 process. MEE condensate was collected for further processing in biological treatment plant and the concentrate was sent to ATFD. The ATFD condensate was collected for further treatment in biological treatment plant and the dried mass from ATFD is packed in high density poly-ethylene bags and sent to safe disposal in to secured landfill. The non-process effluents, MEE condensate and ATFD condensate were sent to the neutralization tank-2 for biological treatment. The stages from the neutralization tank-2 to the RO plant were similar as those in the P-1 process.

3. MATERIALS AND METHODS

3.1.1 Evaluation of quantity

Quantity was evaluated by calculating the percentage yield of treated water and wastewater of the two ZLD treatment plants for a period of 8 months.

3.1.2 Evaluation of time

Time was measured by considering how long it required to treat the effluent for the two ZLD treatment plants.

3.1.3 Evaluation of steam consumption

For each of the two ZLD processes, the amount of treated effluent was calculated using 1 kg of steam.

3.1.4 Evaluation of power consumption

For each of the two ZLD treatment plants, power consumption was calculated using the units obtained from the energy meter.

3.1.5 Evaluation of operational cost

For the two ZLD treatment plants, operational cost was determined by summing up all the expenses of establishment costs, total employee salaries, power charges, solid waste disposal charges, coal cost, and consumables cost.

4. RESULTS & DICUSSION

4.1 Evaluation of quantity

As water scarcity intensifies globally, the recovery and recycling of wastewater has become a major trend. This can be achieved by an innovative wastewater treatment technology, ZLD which involves recycling, recovering and reusing the water without harming the environment **(**Hareesh Gangarapu *et al.,* 2017). Increased public environmental awareness constitutes an additional driver, as ZLD avoids negative environmental impacts of wastewater discharge and reduces the corresponding public concerns (Tong Tiezheng and Menachem Elimelech, 2016).

4.1.1 Water balance of a ZLD treatment plant

Water balance estimation is an important tool to assess the current status and trends in water resource availability in an area over a specific period of time. By using water balance diagram, one can have an idea about the quantity of water which can be used in an industry and the quantity of water which must be recycled to the ZLD treatment plant.

Water balance flow diagram of the two ZLD Treatment Plants was shown in Figure 4.1. In this study, the capacity of the two ZLD treatment plants was 145 KLD. The treated water, permeate was used in cooling towers, washing operations, boiler feed etc., and the reject which consists of solids with 10% moisture was sent to MEE/Batch Evaporator for recycling. Finally, there was no discharge of treated effluent to the environment from the ZLD treatment plant and hence named Zero Liquid Discharge.

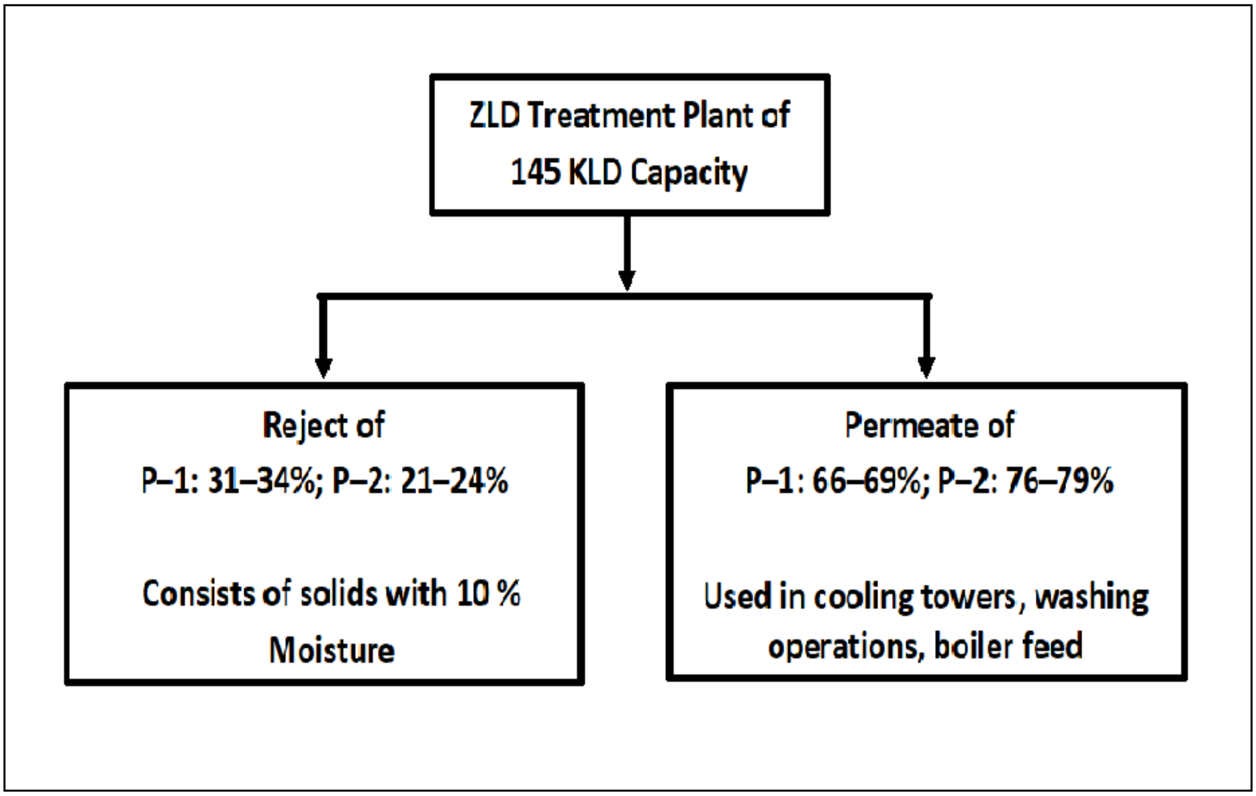

Figure 4.1: Water balance flow diagram

4.1.2 Percentage yield of treated water using ZLD concept

ZLD application is becoming more widespread throughout the world as a crucial wastewater management strategy to reduce water pollution and improve water availability. ZLD treatment plant utilize most current wastewater treatment techniques to clean and recycle almost all of the wastewater generated.

Table 4.1 depicts the amount of treated water & wastewater and Table 4.2 shows the percentage yield of treated water & wastewater of the two ZLD treatment plants. From Figure 4.2, it was observed that percentage yield of treated water ranged from 66-69 % for P-1 and 76-79% for P-2.

Table 4.1: Amount of treated water and wastewater of the two ZLD treatment plants

Process	**P – 1**		**P - 2**	
Month	**Amount of treated water**	**Amount of wastewater**	**Amount of treated water**	**Amount of wastewater**
1	96.7	48.3	111.1	33.9
2	97.4	47.6	112.9	32.1
3	98.5	46.5	112.2	32.8
4	97.6	47.4	113.6	31.4
5	98.3	46.7	110.8	34.2
6	96.6	48.4	112.5	32.5
7	97.9	47.1	113.2	31.8
8	98.7	46.3	111.6	33.4

Table 4.2: % Yield of treated water and wastewater for the three ZLD treatment plants

Process	**P – 1**		**P - 2**	
Month	**% Yield of treated water**	**% Yield of wastewater**	**% Yield of treated water**	**% Yield of wastewater**
1	66.68	33.32	76.62	23.38
2	67.17	32.83	77.86	22.14
3	67.93	32.07	77.37	22.63
4	67.31	32.69	78.34	21.66
5	67.79	33.21	76.41	23.59
6	66.62	33.38	77.58	22.42
7	66.51	33.49	78.07	21.93
8	68.06	31.94	76.96	23.04

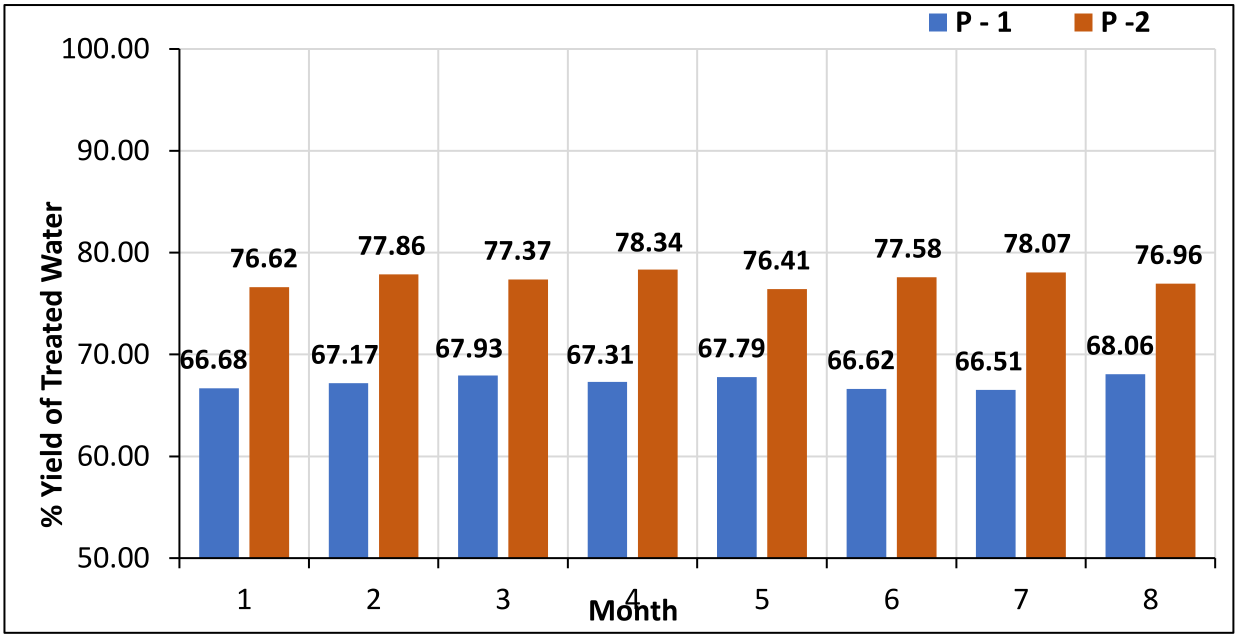

Figure 4.2: Comparison of % yield of treated water for the two ZLD treatment plants

4.2 Evaluation of time

Time is especially reliable in an industrial environment. Throughout industrial operations, the concept of time can vary significantly based on the work, condition, criteria and other factors at play. However, it's one of the most crucial factors for the manufacturers to measure and watch. Time is in fact equal to money.

Even though time taken for P-2 was high as shown in the Figure 4.3, the percentage yield of treated water (76-79%) was also high (Figure 4.2) when compared to P-1. So, P-2 was more efficient than P-1.

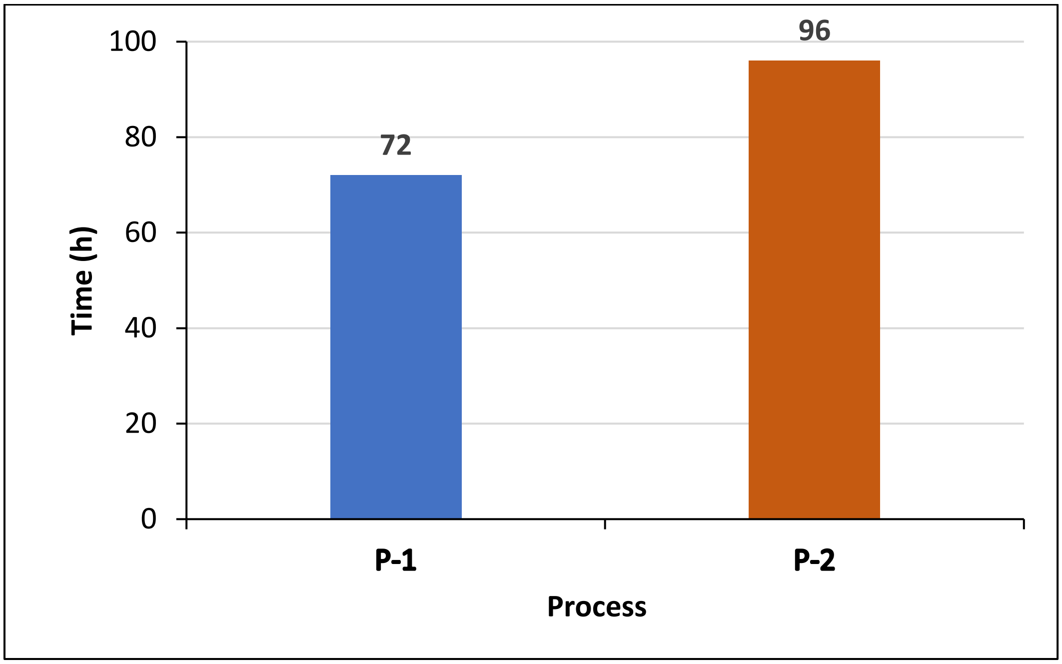

Figure 4.3: Comparison of the two ZLD treatment plants with respect to time

4.3 Evaluation of steam consumption

Today, steam systems are used in practically all significant industrial processes. Hence, industrial sectors pay a lot of attention on steam throughout the world. Steam is employed to generate heat processes as well as to concentrate & distil liquids and also, used in a wide variety of production processes as a heat source, cleaning agent and sterilizer. Effective steam production can save money and resources by using less water and energy (Einstein Dan *et al.,* 2001).

According to Table 4.3, for every kg of steam, 1 L of effluent was treated in P-1, whereas in P-2, 3 L of effluent was treated.

Table 4.3: Steam consumption of the two ZLD treatment plants

Process	**Steam Consumption: Treated Effluent**
P – 1	1:1
P – 2	1:3

4.4 Evaluation of power consumption

Energy utilization per unit of time is referred to as power consumption. Most often, it is expressed in watts. For the economic development of highly developed industrialized nations, an adequate and reliable supply of power is essential. From the very outlet it was clear that power consumption would be of crucial importance for the overall performance and viability of the ZLD concept (Buljan, J *et al.,* 2017).

Figure 4.4 shows that P-2 consumes more power because MEE and ATFD have been replaced by P-1's Batch evaporator and Rotary kiln.

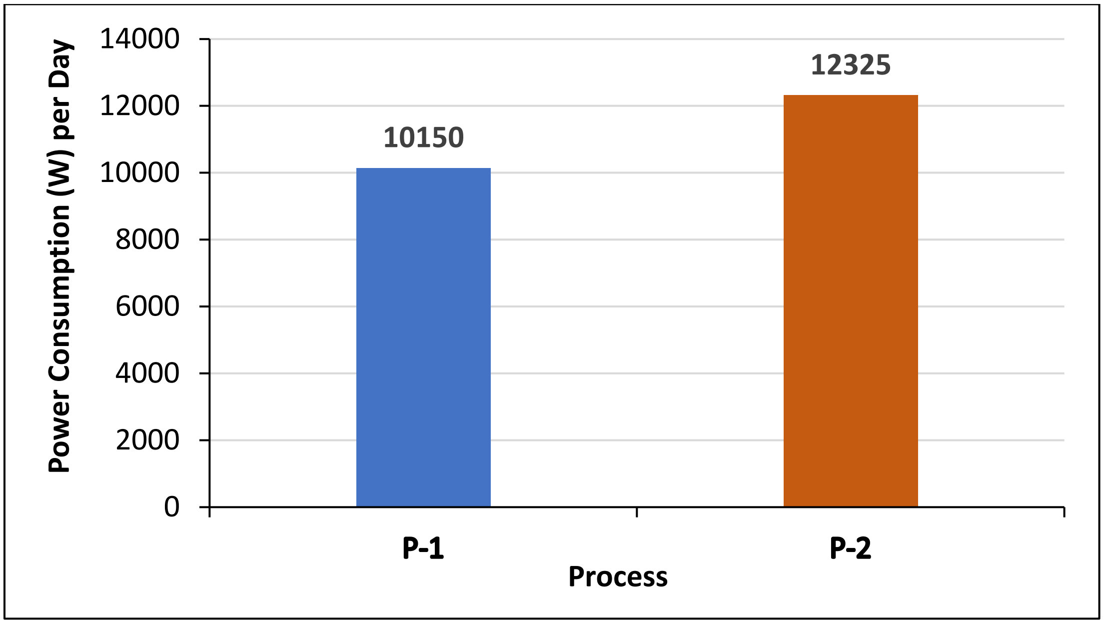

Figure 4.4: Comparison of power consumption for the two ZLD treatment plants

4.5 Evaluation of operational cost

Operating costs are the continuing expenses incurred from the routine day-to-day operations of an Industry. The whole cost of providing a good, service, utility, etc., was referred to as the operating cost.

In this study, operational cost was segregated into establishment cost and process running & maintenance cost. The process running & maintenance per day expenses include personnel salary, power charge, solid waste disposal charge, coal cost and consumables.

Variation of the establishment cost of the two ZLD processes was shown in the Figure 4.5 and represents that P-2 had the highest establishment cost.

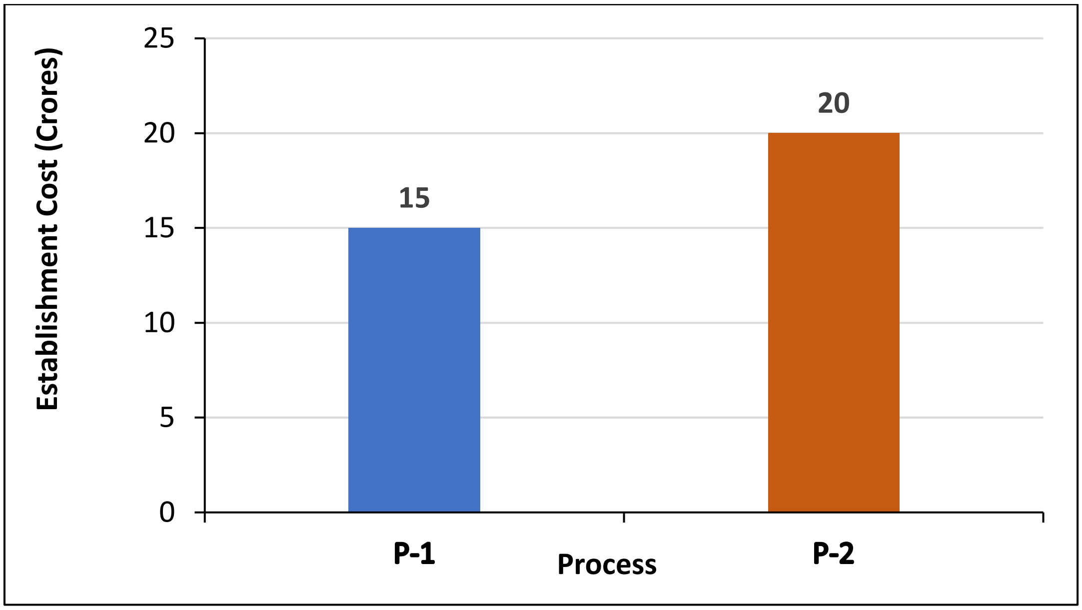

Figure 4.5: Comparison of establishment cost for two ZLD treatment plants

Process running & maintenance cost for the two ZLD treatment plants per day varied as shown in the Table 4.4 and Figure 4.6.

Table 4.4: Process running & maintenance cost of the two ZLD treatment plants

Process **Process running & maintenance Cost (Rs.)**	**P – 1**	**P – 2**
Total Employee Salary per day	33,334	33,334
Power Charge per day	66,667	73,334
Solid waste disposal charges per day	1,60,000	1,33,334
Coal cost per day	6,667	5,000
Consumables cost per day	16,667	16,667
Total	**2,83,335**	**2,61,669**

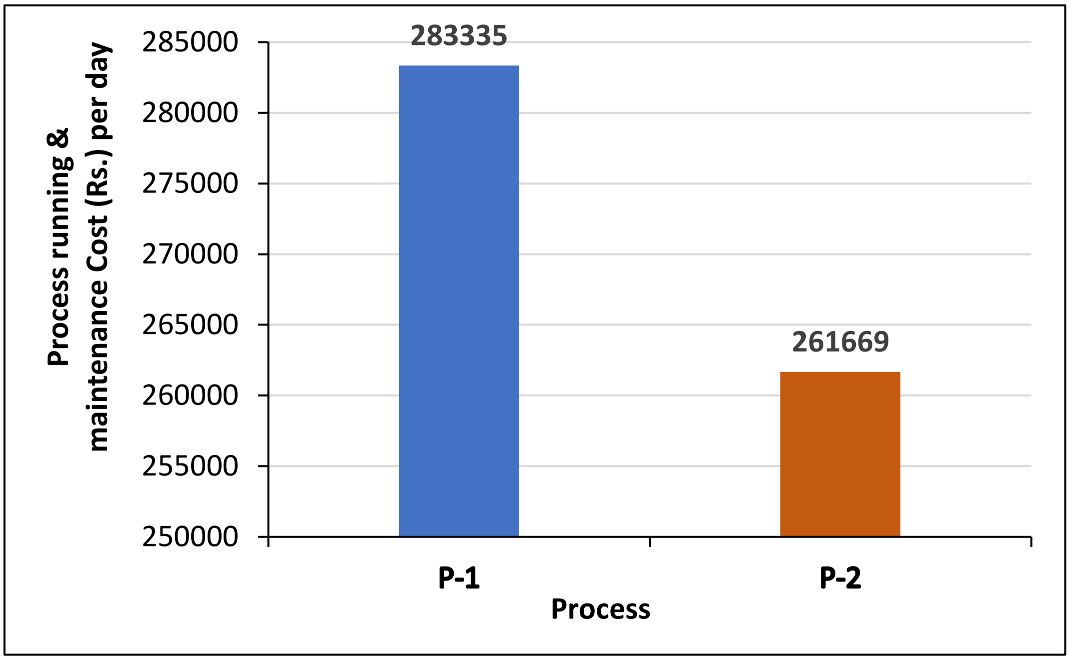

Figure 4.6: Comparison of process running & maintenance cost of the two ZLD treatment plants

Even though time taken, power consumption and operational cost were high for P-2 when compared to P-1 yet P-2 was recommended because more costly noncompliance penalties along with increasing costs for wastewater disposal can outweigh the high expenses of ZLD treatment plant. As a result, P-2 was more reliable than P-1.

5. CONCLUSION

The current study focused on a comparison of two ZLD treatment facilities. Based on the outcomes of this investigation, the following results were concluded:

- Evaluating the quantity, percentage yield of treated water ranged from 66-69 % for P-1 and 76-79% for P-2. Based on quantity, the P-2 ZLD treatment plant was found to be more efficient.
- Time taken for P-2 was high compared to P-1. Despite the time taken for P-2 was high, the percentage yield (76-79%) of treated water was also high. As a result, P-3 was more efficient.

- In P-1, for every kg of steam consumed, 1 L of effluent was treated, whereas in P-2, 3 L of effluent was treated. Thus, P-2 was efficient regarding steam consumption.
- The power consumption per day of P-2 consumes more power because MEE & ATFD were replaced by the Batch evaporator & Rotary kiln of P-1.
- The operational cost of P-2 was high among the two ZLD treatment plants.
- Even though time taken, power consumption and operational cost was high for P-2 when compared to P-1, still P-2 is recommended because more costly noncompliance penalties along with increasing costs for wastewater disposal can outweigh the high expenses of ZLD treatment plant. As a result, P-2 is more reliable than P-1.

6. REFERENCES

[1] Ahirrao, Shrikant. "Zero liquid discharge solutions." *Industrial wastewater treatment, recycling and reuse* (2014): 489-520.

[2] Buljan, J., K. V. Emmanuel, M. Viswanathan, M. Bosnić, and I. Král. "Assessment of performance of Zero Liquid Discharge (ZLD) operations in some tannery clusters Vellore Districts, Tamil Nadu, India." (2017).

[3] Damrongsri, Mongkol, and Sutthirut Pruksanan. "Study of nitrate removal from industrial wastewater treatment effluent by anoxic digester." In *45. Kasetsart University Annual Conference, Bangkok (Thailand), 30 Jan-2 Feb 2007*. 2007.

[4] Duong, Pham-Hung, Cong-Minh Pham, Ngoc-Han T. Huynh, and Yong-Soo Yoon. "Removal of ammonia nitrogen in wastewater by indirect mechanism using electrochemical method with platinum electrode as anode." *Nature Environment and Pollution Technology* 17, no. 4 (2018): 1331-1338.

[5] Einstein, Dan, Ernst Worrell, and Marta Khrushch. "Steam systems in industry: Energy use and energy efficiency improvement potentials." (2001).

[6] El Diwani, G., Sh K. Amin, N. K. Attia, and S. I. Hawash. "Fluoride pollutants removal from industrial wastewater." *Bulletin of the National Research Centre* 46, no. 1 (2022): 1-9.

[7] Fang, Ping, Zi-jun Tang, Xiong-bo Chen, Jian-hang Huang, Zhi-xiong Tang, and Chao-ping Cen. "Removal of high-concentration sulfate ions from the sodium alkali FGD wastewater using ettringite precipitation method: factor assessment, feasibility, and prospect." *Journal of Chemistry* 2018 (2018).

[8] Govindasamy, P., S. D. Madhavan, S. Revathi, and P. Shanmugam. "Performance evaluation of common effluent treatment plant for tanneries at Pallavaram CETP." *Journal of Environmental Science and Engineering* 48, no. 3 (2006): 213.

[9] Hareesh, Gangarapu, Sija Arun, and Dr P. Shanmugam. "Comparative analysis of multiple effect evaporators and anaerobic digester (UASB) for an effective management of RO reject from tannery." *Int. J. Civ. Eng* 8, no. 4 (2017): 809-815.

[10] Hovel, Thekla. "Discussion of Zero Liquid Discharge as a solution for desalination brine management-A case study at Desolenator’s project in Dubai." (2021).

[11] Liang, Yinglin, Xin Lin, Xiangtong Kong, Qiushi Duan, Pan Wang, Xiaojie Mei, and Jinxing Ma. "Making waves: Zero liquid discharge for sustainable industrial effluent management." *Water* 13, no. 20 (2021): 2852.

[12] Maheswara, Uma, Rao Ganguru, and Sunil Kulkarni. "Studies on Zero Liquid Discharge (ZLD) Plant in API Manufacturing Unit." *environment* 6, no. 7 (2015).

[13] Nibe R. L, Hinge R.V and Divate S.B. “Wastewater Treatment by Zero Liquid Discharge Process (ZLD*).” Journal of Emerging Technologies and Innovative Research* 9, no. 4 (2022): e237-241.

[14] Ranade, Vivek V., and Vinay M. Bhandari. *Industrial wastewater treatment, recycling and reuse*. Butterworth-Heinemann, 2014.

[15] Ranganathan, Kuppusamy, and Shreedevi D. Kabadgi. "Studies on feasibility of reverse osmosis (membrane) technology for treatment of tannery wastewater." *Journal of Environmental Protection* 2, no. 01 (2011): 37.

[16] Reddy, Sareddy Ravi Sankara, Manoj Kumar Karnena, Bhavya Kavitha Dwarapureddi, and Vara Saritha. "Treatment of Effluents Containing High Total Dissolved Solids By Multi-Effect Evaporator." *Nature Environment and Pollution Technology* 19, no. 3 (2020): 1173-1177.

[17] Sankar Raja P, Rajesh S. “A Study on Zero Liquid Discharge Plant for Dyeing Industry.” *International Journal of Scientific Engineering and Research* (2015): 2347-3878.

[18] Singh, Jaidev. "Effluent Treatment Plant: Design, Operation and Analysis of Waste Water." (2012).

[19] Tong, Tiezheng, and Menachem Elimelech. "The global rise of zero liquid discharge for wastewater management: drivers, technologies, and future directions." *Environmental science & technology* 50, no. 13 (2016): 6846-6855.

DOI: https://doi.org/10.15379/ijmst.v10i2.2963