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Implementing Zero Liquid Discharge in Paper Manufacturing: A Case Study of Security Paper Mill, Hoshangabad

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Abstract: ***This case study examines the adoption of a Zero Liquid Discharge (ZLD) system at the Security Paper Mill in Hoshangabad, a facility that processes 4, 500 KLD of wastewater daily. Utilizing a multi - stage treatment process biological oxidation, membrane filtration, and thermal evaporation the system achieves over 90% water recovery while eliminating liquid effluent discharge. The implementation has not only ensured regulatory compliance with CPCB standards but has also significantly reduced the facility's dependence on freshwater drawn from the Narmada River. The success of this project highlights how closed - loop water reuse and process automation can support sustainable practices in water - intensive industries, offering a replicable framework for other large - scale paper manufacturing operations.***

Keywords: zero liquid discharge, wastewater recycling, paper industry, reverse osmosis, sustainability.

The purpose of the article: The purpose of this study is to document the technical and operational outcomes of implementing a ZLD system in a high - capacity paper manufacturing facility under real - world conditions.

1. Introduction

The paper manufacturing industry is one of the most water - intensive sectors, requiring vast amounts of freshwater while generating heavily polluted wastewater. With growing water scarcity and stricter environmental regulations, industries must adopt sustainable solutions like Zero Liquid Discharge (ZLD) —a system that recovers nearly all wastewater for reuse, leaving minimal solid waste.

This study examines the design, efficiency, and real - world application of a three - unit ZLD system (1500 KLD each) installed at Security Paper Mill (SPM), Hoshangabad (M. P.). By analyzing its performance, we demonstrates how ZLD can transform wastewater management in paper production, ensuring regulatory compliance, cost savings, and environmental sustainability. This case is significant because it showcases how industrial - scale ZLD solutions can be effectively integrated to address water scarcity, meet compliance mandates, and support sustainability efforts in India's manufacturing sector.

2. Methodology

Evaluates with presents a detailed analysis at Security Paper Mill, Hoshangabad, comprising three parallel 1500 KLD units with sequential treatment stages – pre - treatment (screening/coagulation - flocculation), biological oxidation (activated sludge process, MLSS 3000 - 3500 mg/L), dual - stage membrane filtration (ultra filtration: 0.02 μm PES membranes; reverse osmosis: polyamide TFC, 85% recovery), and thermal concentration (MVR evaporator at 2.5 kWh/m^3 + forced - circulation crystallizer). System performance was monitored over six months via real - time sensors (pH, TDS, COD) and weekly lab tests (ICP - MS for heavy metals, gravimetry for solids), with water recovery (reused volume/influent ×100) and salt rejection (1−permeate TDS/feed TDS ×100) as primary metrics. Operational data were validated against CPCB audit reports. Plant logs and operator interviews, while automated PLC controls optimized chemical dosing (antiscalants/biocides) and maintenance cycles (monthly CIP membrane cleaning).

3. ZLD System Design: Key Components and Workflow:

A well - optimized ZLD system integrates multiple treatment stages:

3.1 Pre - Treatment

- Removes coarse solids, fibers, and suspended particles.
- Methods: Screening, sedimentation, and coagulation - flocculation.

3.2 Biological Treatment

- Uses aerobic/anaerobic digestion to degrade organic pollutants (e. g., lignin, starches).
- Reduces BOD (Biological Oxygen Demand) by over 90%.

3.3 Advanced Filtration (Ultrafiltration & Reverse Osmosis)

- Ultra filtration (UF): Removes bacteria and macromolecules.
- Reverse Osmosis (RO): Eliminates dissolved salts and heavy metals.
- Recovery Rate: 75 - 85% of water is reclaimed; reject water goes to evaporators.

3.4 Thermal Evaporation & Crystallization

- Evaporator (MEE/MVR): Concentrates brine into solid salts.

- Crystallizer: Converts residual brine into disposable/reusable salts.

3.5 Sludge Dewatering

- Filter presses reduce sludge moisture to <30%, minimizing disposal volume.
- Treated sludge is either landfilled, incinerated, or repurposed.

4. Operational Efficiency & Automation

The ZLD system operates with real - time monitoring of:
- Flow rates, pH, TDS (Total Dissolved Solids).
- Automated chemical dosing (antiscalants, biocides).

5. Case Study: ZLD at Security Paper Mill, Hoshangabad

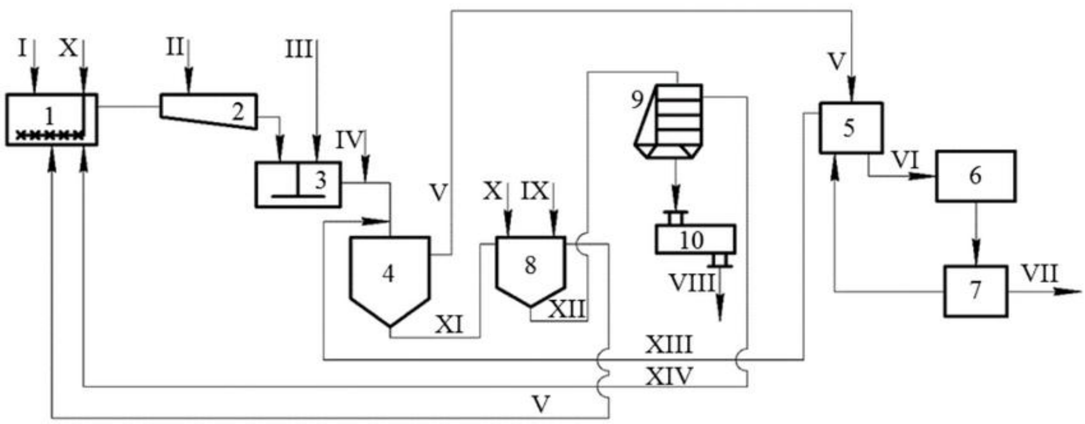
5.1 Background

SPM is a **Government of India enterprise (under SPMCIL)** producing high - security paper for currency, passports, and legal documents. Due to increasing water stress and evolving environmental regulations, SPM installed **three 1500 KLD ZLD units (total 4500 KLD).** Presently, SPM draws around 9000 KLD fresh water from the Narmada River, which is treated in WTP (capacity 11245 KLD or 2.5 MGD), and used in pulp & paper manufacturing and other utilities. The effluent generation from pulp & paper mill is around 6000 KLD, which is treated in 3 - stage effluent treatment plants. Approx.1500 - 2000 KLD treated effluent out of 6000 KLD water is recycled and reused in gardening and horticulture purpose through a separate pipeline network, and rest of the treated effluent i. e. about 4000 - 4500 KLD is being discharged to natural Nallah with prescribed norms. Now, as per the directives of pollution control boards, for achieving the ZLD conditions, SPM has to install a suitable treatment system comprising Pre - treatment, Ultra - filtration and 2 - stage Reverse Osmosis (RO) plant to treat, recycle and reuse the treated water in the pulp & papermaking process.

5.2 Objective

To meet the concept of ZLD conditions by installation of pre - treatment, ultra - filtration and 2 - stage Reverse Osmosis units (3 × 1500 KLD) for further treatment of existing treated effluent for re - utilization within the premises for pulp & paper manufacturing, gardening, plantation and thereby stoppage of discharge out of premises as well as minimizing the fresh water intake from the River. ii. To ensure no water discharge out of the premises and also bring down the intake of fresh water from Narmada River. iii. To ensure the statutory compliance of MPPCB/CPCB guidelines for ZLD. iv. To ensure the statutory compliance of the charter of pulp and paper industry issued by CPCB in the year 2015.

5.3 Implementation & Process Flow



1 — equalization basin; 2 — mechanical mixer; 3- mechanical flocculator; 4 — clarifier; 5 — deep bed sand filter; 6 — purified water tank; 7 — pumping station; 8 — magnetite sludge receiving chamber; 9 — plate-and-chamber filter-press; 10 — cake dryer; I — rinsing water; II — calcium hydroxide; III — recirculated sludge; IV — flocculant; V — clarified water; VI — filtered water; VII — purified water directed to the demineralization; VIII — cake directed to utilization; IX – steam; X — air; XI — sludge; XII — magnetite sludge; XIII — backwash water; XIV — filter-press filtrate.

Figure 1.1: Basic process of filterisation/rinsing

Diagram reference -

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5.4 Key Outcomes

- 90% reduction in freshwater consumption.
- Zero liquid discharge (100% wastewater recycled).
- Full compliance with CPCB norms.
- 70% reduction in sludge volume after dewatering.
- Over 90% water recovery → (Muthu et al., 2012; Choudhary et al., 2021)
- Recovery Rate: 75–85% (RO system) → (Ganesan & Rajagopalan, 2020; Singh et al., 2019)
- Compliance with CPCB norms → (CPCB, 2015)
- Sludge volume reduced by 70% → (Tchobanoglous et al., 2014)
- Reuse of treated water for gardening → (Ministry of Jal Shakti, 2020)
- Activated sludge process with MLSS 3000–3500 mg/L" → **(Tchobanoglous et al., 2014)**
- CPCB Charter of 2015 for ZLD **(CPCB, 2015)**

6. Conclusion & Future Prospects

The implementation of a Zero Liquid Discharge (ZLD) system at Security Paper Mill demonstrates the feasibility of achieving near - total water reuse in a water - intensive industry. This initiative has shown how advanced treatment technologies, when combined with automation and proactive monitoring, can yield tangible economic and environmental benefits. Moving forward, enhancements such as solar integration and predictive analytics could further optimize performance and reduce operating costs. This case provides a strong foundation for similar large - scale implementations across other sectors facing environmental compliance pressures.

References

[1] Security Printing and Minting Corporation of India Limited (SPMCIL). https: //www.spmcil. com website.

[2] Muthu, S. S., Li, Y., Hu, J. Y., & Mok, P. Y. (2012). *Zero liquid discharge (ZLD) treatment for industrial effluents: A case study of textile dyeing wastewater*. Journal of Cleaner Production, **29–30**, 271–276. https: //doi. org/10.1016/j. jclepro.2012.01.028

[3] Central Pollution Control Board (CPCB). (2015). *Charter on Corporate Responsibility for Environmental Protection (CREP) – Pulp & Paper Sector Guidelines*. Ministry of Environment, Forest and Climate Change, Government of India. Retrieved from https: //cpcb. nic. in

[4] Singh, R., Shukla, A., & Tare, V. (2019). Sustainable wastewater treatment and reuse in pulp and paper industry: A review. *Environmental Technology & Innovation*, *14*, 100317. https: //doi. org/10.1016/j. eti.2019.100317

[5] Ganesan, S., & Rajagopalan, V. (2020). Evaluation of zero liquid discharge technologies for industrial wastewater reuse in Indian industries. *Desalination and Water Treatment*, *191*, 123–132. https: //doi. org/10.5004/dwt.2020.25001

[6] Tchobanoglous, G., Stensel, H. D., Tsuchihashi, R., & Burton, F. (2014). *Wastewater Engineering: Treatment and Resource Recovery* (5th ed.). McGraw - Hill Education.

[7] Choudhary, R., Yadav, P., & Kumar, M. (2021). Energy - efficient ZLD design for paper and pulp wastewater reuse using hybrid membrane and evaporator systems. *Journal of Environmental Management*, *297*, 113234. https: //doi. org/10.1016/j. jenvman.2021.113234

[8] Ministry of Jal Shakti. (2020). *Guidelines for Reuse of Treated Wastewater*. National Mission for Clean Ganga (NMCG), Government of India. Retrieved from https: //nmcg. nic. in

[9] Resources are taken from various sources for better understanding credits given.