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Zero Liquid Discharge (ZLD) Systems In Paper M anufacturing: "Implementation And Operational Analysis At Security Paper Mill, Hoshangabad"

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Abstract

the paper manufacturing industry faces mounting pressure to reduce freshwater consumption and eliminate wastewater discharge. This study evaluates the implementation of a Zero Liquid Discharge (ZLD) system at Security Paper Mill, Hoshangabad - a three-unit (1500 KLD each) facility treating 4500 KLD of process wastewater daily. The integrated treatment cascade (biological oxidation, ultrafiltration, reverse osmosis, and thermal evaporation) achieves 90% water recovery and complete elimination of liquid effluent. Operational data demonstrate compliance with CPCB norms while reducing freshwater intake by 4,050 KLD/day. The case study establishes ZLD as both technically viable and economically sustainable for large-scale paper mills, with particular relevance to water-stressed regions. Key success factors include automated process control, sludge volume minimization through filter presses, and closed-loop water reuse for boiler feed and pulp washing. These findings provide a replicable model for the pulp/paper industry's transition to circular water economies.

Keywords: Zero Liquid Discharge (ZLD), paper manufacturing, wastewater treatment, water recycling, reverse osmosis, ultrafiltration, evaporator, crystallizer, Security Paper Mill Hoshangabad, industrial water conservation, circular water economy, CPCB compliance, sludge dewatering, mechanical vapor recompression (MVR), activated sludge process, sustainable pulp industry, India, closed-loop systems, TDS reduction, process automation.

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 demonstrate how ZLD can transform wastewater management in paper production, ensuring regulatory compliance, cost savings, and environmental sustainability.

2. Methodology

This study evaluated a 4500 KLD Zero Liquid Discharge (ZLD) system 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 (ultrafiltration: 0.02 µm PES membranes; reverse osmosis: polyamide TFC, 85% recovery), and thermal concentration (MVR evaporator at 2.5 kWh/m³ + 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)

Ultrafiltration (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).

AI-driven optimization for energy and cost efficiency.

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. Facing water scarcity and regulatory pressure, 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 i. 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

5.4 Implementation and Operational Analysis

The Security Paper Mill (SPM), Hoshangabad, undertook the implementation of a Zero Liquid Discharge (ZLD) system to enhance environmental compliance and water sustainability. The plant's performance was assessed based on operational variables including water recovery rate, energy consumption, sludge generation, chemical usage, and cost metrics. The data was collected over a period of 12 months.

5.4.1 Descriptive Statistics of Study Variables

Variable	Mean	Median	Standard Deviation	Min	Max
Water Recovery Rate (%)	92.5	93	2.1	87	96
Energy Consumption (kWh/m³)	1.8	1.75	0.3	1.3	2.4
Sludge Generation (kg/day)	780	775	45	700	860
Chemical Usage (kg/m³)	0.45	0.44	0.05	0.38	0.52
Operating Cost (INR/m³)	54.7	55	4.2	47	62

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.

6. Conclusion & Future Prospects

The three-unit ZLD system (1500 KLD each) at SPM proves that large-scale ZLD is technically and economically viable for paper mills. Future improvements could include:
Solar-powered evaporation to cut energy costs.
Salt recovery for industrial reuse.
AI-based predictive maintenance for long-term efficiency.
As water stress increases, ZLD will shift from an optional upgrade to an industry necessity.

7. References

Security Printing and Minting Corporation of India Limited (SPMCIL).
Central Pollution Control Board (CPCB) – Effluent Treatment Guidelines.
Journal of Cleaner Production – ZLD Case Studies.
Resources are taken from various sources for better understanding credits given.