



Cotton Comber Fibre and Energy Recovery Practices at BNPM for Sustainable Pulping



Vishal Kumar*
Deputy Manager



S Muthukumar *
Deputy Manager



Megavath Sarvesh*
Deputy Manager



Manoj Gupta *
Deputy General Manager

Bank Note Paper Mill India Pvt. Ltd.,
Mysuru

Abstract: *The pulp and paper industry is increasingly focusing on renewable bioresources, circular material use, and energy efficiency to achieve sustainable manufacturing. In non-wood-based pulping systems, efficient utilization of raw material, recovery of fibres, and optimization of energy and water play a critical role in reducing specific consumption and improving productivity. This paper presents the Pulping Plant practices at Bank Note Paper Mill India Pvt. Ltd. (BNPM), where Cotton Comber, a renewable agricultural bioresource, is used as the primary raw material. The study highlights how integrated fibre recovery, heat recovery, and by-product utilization initiatives have contributed to improved material efficiency, reduced energy consumption, and enhanced overall process performance. Special emphasis is given to fibre recovery systems implemented in both dry and wet sections of the pulping plant. Fibre recovery from the dry section through dedicated recovery systems has significantly reduced fibre losses approx. 30% of usable cotton comber fibres from pre-briquetting stage are recovered through Fibre Recovery System. Wet fibre recovery from pulp effluent using a 500-micron static filter has enabled reclamation of usable fibres before discharge. Additionally, fibre morphology samples after online analysis are reused back into the system, further improving fibre yield and circularity. Thermal energy efficiency initiatives include heat recovery from hot effluent streams using heat exchangers to preheat boiler feed water, resulting in reduced furnace oil consumption and improved boiler efficiency. The paper also discusses the handling of dry rejects generated during pulping, which are converted into briquettes and sold externally for transforming waste into a value-added by-product. Effluent generated in Pulping Plant is treated in Effluent Treatment Plant and treated water is used for process and gardening. The combined impact of fibre recovery, effluent reuse, process optimisation and heat recovery has led to improved productivity and reductions in specific energy, water, and raw-material consumption. The paper concludes by demonstrating how focused pulping-plant-level interventions can effectively support renewable bioresource utilization, energy efficiency, and sustainable manufacturing, offering a replicable model for non-wood-based pulp mills.*

Keywords: *Cotton Comber, Dry Fibre recovery, Wet Fibre recovery, Effluent Treatment, Waste Heat Recovery.*

Introduction

The Indian pulp and paper industry is undergoing a transition driven by sustainability goals, rising energy costs, and the need for efficient utilization of renewable bioresources. Non-wood-based pulping systems play a vital role in ensuring fibre security while reducing dependence on forest-based raw materials. However, such systems require careful management of fibre losses, energy consumption, water usage, and waste generation to remain economically and environmentally sustainable.

Cotton fibre has been used for banknote paper due to its high alpha cellulose content, absence of lignin, excellent fibre strength, and resistance to ageing and repeated folding. Compared to wood based fibres, cotton fibres offer higher tensile strength, tear strength, and dimensional stability, which are essential properties for banknote paper subjected to continuous handling.

Cotton comber, generated as a by-product of the textile industry, is a renewable bioresource with high cellulose content and consistent fibre characteristics, making it suitable for specialty paper applications. BNPM has adopted cotton comber as the primary raw material for manufacturing of banknote paper.

We have continuous pulping plant, state of the art technology, and have implemented a series of process-level improvements focused on fibre recovery, energy efficiency, and circular resource utilization. This paper documents these initiatives and their contribution towards sustainable pulping.

2. Cotton Comber as a Renewable Bioresource

Cotton Comber is an agricultural product obtained during cotton processing and combing operations in the spinning mills. During combing short fibres and impurities are removed to improve yarn quality resulting in separation of cotton comber material. Cotton comber contains short but high purity cotton fibres typically with fibre lengths of up to 20 mm making it suitable for pulping application. It also offers several advantages as a raw material for banknote paper:

- Renewable and non-wood origin
- High alpha-cellulose content
- Good fibre strength
- No lignin
- Consistent fibre morphology

Utilization of cotton comber supports circular economy principles by converting an agricultural product into a high-value industrial input. At BNPM, systematic handling and processing of cotton comber enable stable pulp quality.

3. Overview of Pulping Plant Operations at BNPM

The pulping plant at BNPM is designed to efficiently process cotton comber into high-quality pulp. Key operational stages include:

- Raw material preparation and feeding
- Dry Cleaning and Wet Cleaning
- Bleaching, Cooking and Washing
- Pulping and Refining
- Reject handling and disposal
- Effluent generation and treatment

The plant emphasizes on quality, process stability, fibre yield maximization, and minimization of losses across both dry and wet sections.

4. Fibre Recovery Practices

4.1 Dry Fibre Recovery System in Cotton Comber Pulping

In Cotton Comber-based pulping operations, significant fibre losses occur during dry handling and cleaning stages due to pneumatic conveying and dust separation. At BNPM, the dry cleaning system consists of multiple stages including Bale Plucker, Air Separator, Cyclone Separator, Step Cleaner, Light waste and colour particles removal, Metal Detector, Reserve Tower, and Densifier. During these stages, a portion of good-quality cotton fibres was getting mixed with dust (coarse particles and fines) conveyed to the Air Filtration Unit (AFU) as shown in Figure 1, where it was subsequently briquetted along with contaminants, leading to loss of usable fibres. To address this issue, a Dry Fibre Recovery System has been installed and commissioned at the pulping plant as a dedicated process improvement initiative. The system is designed to recover usable cotton fibres from exhaust streams of the Reserve Tower and Densifier, which were identified as major sources of fibre loss as mentioned in Table 1. The fibres recovered were analysed to confirm their suitability for reuse, and after validation, the recovered fibres were introduced into the system as per subsequent section, without any adverse impact on pulp quality.

Table 1: Source of Fibre Loss & Recovery Points

Sample Location	Waste Collected (1 hour) in kg.	Individual waste weight/Total waste weight in %.
Densifier	1.18	13.47%
Reserve Tower	2.48	28.31%
Air Separator & Step Cleaner	5.10	58.22%

The dry fibre recovery system consists of two fibre separators, one for each cotton handling line. The exhausts from the Reserve Tower and Densifier were diverted from the existing AFU to the fibre separators as shown in Figure 2. Within the separator, centrifugal and air-flow-based separation enables segregation of usable cotton fibres from dust.

Recovered fibres are transferred back into the process intermittently by routing them to the step cleaner feed line through controlled pneumatic shutoff valves. The system operates using the existing suction pressure of the step cleaner, maintained at approximately -1600 Pascal's, ensuring seamless integration without disturbing the air balance of the cleaning system. The exhaust air from the fibre separators is routed back to the AFU, thereby maintaining environmental and dust control standards.

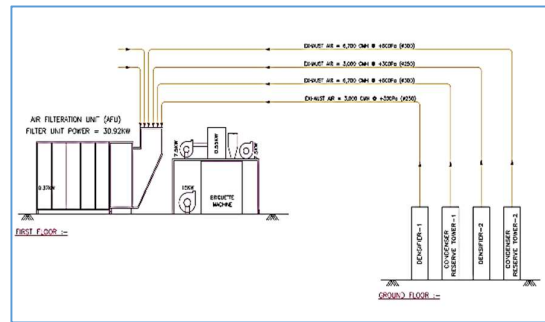


Fig 1: Waste Collection Unit / AFU (Before)

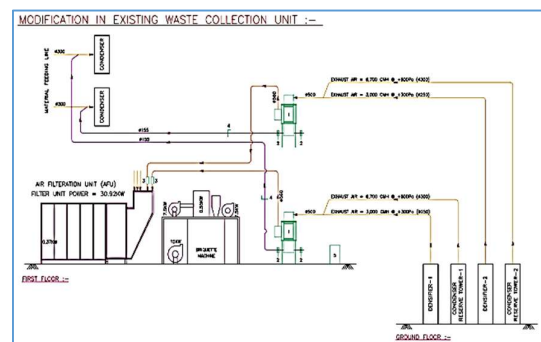


Fig 2: Waste Collection Unit / AFU (After)

Automation, Control, and Safety Features

The entire dry fibre recovery system is controlled through a PLC-based control panel, integrated with pressure transmitters and pneumatic actuators. A Digital Monitoring System (DMS) enables continuous monitoring of operating parameters such as suction pressure, valve status, and system condition.

To ensure operational safety and reliability:

- High and low pressure limits are defined for the fibre separator inlet.
- In case of abnormal pressure deviation, visual and audible alarms are generated.
- Automatic bypass logic diverts the exhaust directly to the AFU, in case of system malfunction or compressed air failure. These safeguards ensure uninterrupted pulping plant operation and prevent process disturbances.

Performance and Benefits

Dry fibre recovery system has demonstrated consistent performance since commissioning as mentioned in Table 2. Approximately 30 to 40% of usable cotton comber fibres (Approximately ~ 150 to 200 kg / Day) from the briquetting stage are now recovered and reused in the pulping process. The key benefits achieved include:

- Significant reduction in raw material losses
- Improved fibre yield and material efficiency
- Reduction in waste generation sent for briquetting
- Improved overall productivity of the pulping plant

The system has stabilized fibre flow, reduced variability in pulping operations, and strengthened circular resource utilization in cotton comber-based pulping.

Table 2: Dry Fibre Recovery System - Performance

Summary.		
Parameter	Before Installation	After Installation
Fibre sent to briquetting	High	Significantly Reduced.
Usable Fibre Recovery	NIL	30-40%
Cotton Recovery	NIL	150-200 kg/Day

Table 3: Wet Fibre Recovery via Static Filter.

Parameter	Observation
Screen Size	500 Micron
Fibre recovered	250-300 kg/ Day
Impact on ETP	Reduced BOD / TSS load.
Energy Requirement	Nil (Gravity Based)
Maintenance	Low

4.2 Wet Fibre Recovery from Pulp Effluent using Static Filter.

In cotton comber-based pulping operations, a portion of usable fibres is inevitably carried over with pulp effluent during washing stage. If not recovered, these fibres contribute to raw material loss and increase the solid load on the effluent treatment system. To enhance fibre utilization and support circular resource use, BNPM has implemented a wet fibre recovery system using a static filter in the pulping plant effluent circuit.

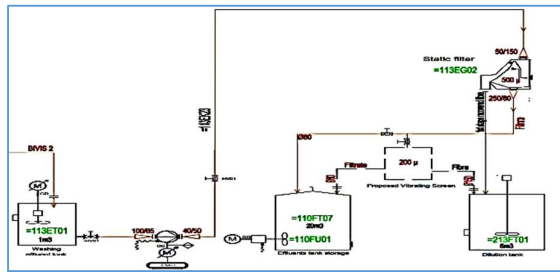


Fig 3: Static Filter Line Diagram.

System Description and Process Integration

The wet fibre recovery system is installed in the pulp effluent line downstream of the washing section. Pulp effluent from the washing effluent tank is routed to a static filter equipped with a 500-micron screening surface, as shown in the process schematic Figure 3. The static filter operates without rotating parts, utilizing gravity and hydraulic head to separate suspended fibres from the effluent stream.

As the effluent passes over the screen surface, usable fibres are retained on the screen and collected as first-stage recovered fibre, while the filtrate passes through the screen openings. The recovered fibres are directed back to the intermediate pulp transfer tank, where they are reintroduced into the pulping process. The fibres recovered have been analysed in the R&D laboratory to confirm their suitability for reuse. This ensures that fibre recovery does not adversely affect pulp quality (Brightness, pH and Consistency) or process stability.

The clarified filtrate from the static filter is routed to the effluent storage tank and subsequently treated in the effluent treatment plant. Provision has also been made for secondary screening through a vibrating screen, if required, to enhance recovery efficiency and operational flexibility. A washing shower arrangement is provided for periodic cleaning of the static filter to ensure consistent filtration and uninterrupted operation.

Operational Performance and Benefits

The static filter system has demonstrated stable and reliable operation under varying process conditions as mentioned in Table 3. The key benefits achieved include:

- Recovery of usable fibres from pulp effluent that were previously lost, (~250 to 300 kg/Day).
- Reduction in suspended solids load entering the effluent treatment plant thereby reducing the biological oxygen demand (BOD), chemical consumption and operation cost in ETP.
- Improved overall fibre yield and raw material utilization efficiency
- Contribution to effluent generation with low solids.

4.3 Reuse of Fibre Morphology Samples

Online pulp quality monitoring is essential for maintaining consistent product quality in specialty paper manufacturing. At BNPM, pulp freeness and fibre morphology are continuously monitored using an online analyser installed in the refiner area. Online measurement enables real-time control of refining intensity to ensure uniform pulp characteristics.

Earlier, the pulp samples drawn for online analysis were drained after measurement, resulting in avoidable fibre loss and additional effluent generation. The analyser is capable of analysing up to 240 samples per day across both pulping lines, with each sample consisting of low-consistency pulp slurry. Discarding these samples not only led to loss of usable fibres but also increased the fresh water consumption (100-120 litre/Sample) and solids load on the effluent treatment system.

To address this issue, a fibre recovery system for analyser drain samples has been implemented as shown in Figure 4. The low-consistency pulp slurry collected from the analyser drain is routed to a dedicated collection tank and pumped back into the process bleached pulp chest. Automatic flow control arrangements enable directing the recovered pulp to either pulping line based on operational requirements.

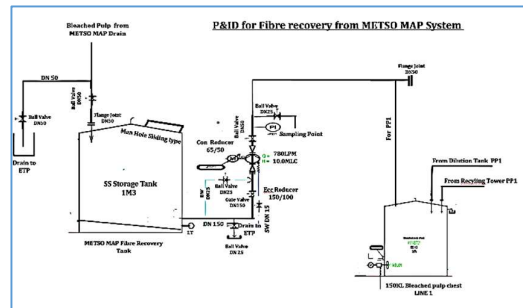


Fig 4: Reuse of Fibre Morphology Samples – Line Diagram.

This initiative has resulted in effective recovery and reuse of fibre morphology and freeness analysis samples, leading to a reduction in fibre loss, specific fresh water consumption, and effluent generation as mentioned in Table 4. The effluent outflow from the pulping plant has been reduced by 20-25 m³ per day, thereby lowering the load on the effluent treatment plant. Additionally, reuse of analysed pulp has contributed to cost and energy savings.

The reuse of morphology and freeness analysis samples demonstrates how small, process-level interventions can significantly enhance material circularity, water conservation, and overall sustainability in pulping operations, without compromising product quality or process control.

Table 4: Benefits from Reusing Morphology Samples.

Aspect	Impact
Samples analysed	Up to 240 / Day
Water used for 1 Sample	100-120 Litres
Fresh water recovered	20-25 m³ / Day
Fibre recovered	4-6 MT/Year
Effluent Load	Reduced.

5. Heat Recovery and Thermal Energy Optimization (Heat Recovery from Hot Effluent)

Hot effluent generated during pulping contains recoverable thermal energy. BNPM has installed heat exchangers to transfer heat from hot effluent streams to boiler feed water.

Benefits achieved include:

- Preheating of boiler feed water
- Reduction in furnace oil consumption
- Improved boiler efficiency
- Reduced thermal energy losses

This waste heat recovery initiative contributes directly to energy efficiency and reduced fossil fuel usage.

6. Effluent Treatment and Water Reuse

Effluent generated in the pulping plant is treated in the Effluent Treatment Plant (ETP). Treated water is reused for:

- Process applications
- Gardening and utility purposes

Water reuse reduces fresh water intake and contributes to lower specific water and energy consumption across the plant.

7. Reject Management

Dry rejects generated during pulping operations and sludge generated during effluent treatment are converted into briquettes and sludge respectively. These briquettes and sludge are sold externally, transforming waste into a value-added by-product.

This approach:

- Reduces landfill disposal

- Generates additional revenue
- Enhances material circularity

By-product utilization aligns with sustainable manufacturing and waste-to-value principles.

8. Discussion

The BNPM experience illustrates that focused pulping-plant-level interventions can deliver significant sustainability benefits without requiring major capital investments. Fibre recovery, energy recovery, and by-product utilization are especially critical for pulping systems, where raw material efficiency and process stability directly influence overall performance.

The practices described are technically simple, operationally robust, and scalable, making them sustainable.

9. Conclusion

Sustainable pulping requires efficient utilization of renewable bioresources, recovery of fibres and energy, and responsible waste management. BNPM's cotton comber-based pulping operations demonstrate that systematic fibre recovery from dry and wet sections, heat recovery from hot effluent, reuse of treated effluent water, and value-added utilization of rejects can significantly improve energy efficiency, productivity, and circularity.

The initiatives presented in this paper offer a replicable framework for pulp mills aiming to align with renewable bioresource utilization and sustainability objectives.

10. Acknowledgement

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