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Closing water loop in a paper mill section for water conservation and reuse

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ABSTRACT

Water is critical to paper production and increasing competition from other users has reduced water availability to paper mills in recent years. The study was conducted at a large-scale integrated pulp and paper industry. The study conducted at laboratory for recycling of effluents was aimed at reducing water foot print of the paper mill. Paper machine section effluent was identified for treatment and reuse based on the flow and characteristics. Chemical aided clarification and simple membrane filtration systems were used for water recovery. Closing the water loop through suitable treatment for reuse of wastewater in the paper mills provides an assured and continuous source of water. Pollutant reductions at the rate of 87.5%, 75% and 89% were obtained on SS, COD and turbidity, respectively. Operational and capital costs were delineated for selection of treatment option and enhanced water recovery. Feasibility of micro/ultra filtration combination was assessed to reduce costs for water recovery. This combination removed up to 93% and 91.7% of SS and COD from the effluents. The treatment options assessed for water recovery reduced freshwater consumption by about 40% and the excess treated water was stored in ponds for process use during the lean season.

1. Introduction

The demand for paper consumption in India is anticipated to grow exponentially in the next few decades, as the existing per capita paper consumption is the lowest among developing and developed nations at 9.2 kg as of 2009 [1]. This is less than the quantity required (40 kg per capita annually) to meet basic needs of communication and literacy [2]. The per capita paper consumption in China is 42 kg and 350 kg in the US for comparison [3]. About 600 pulp and paper mills operate in India, with an installed capacity of 9.2 million tonnes per annum (MTPA) during 2010 [3]. Papers of different grades are produced such as printing, writing, packaging and speciality papers. Currently, an average pulp and paper mill in India consumes about 135 m^3 of water per ton of paper produced [4]. Acceptance of Corporate Social Responsibility (CREP) by the paper mills proposed by the national regulatory agency, Central Pollution Control Board, Delhi accounted for significant water conservation through good house practices in the last decade.

Paper manufacturing requires water for various unit operations in particular for cellulose dissolution, pulp washing and preparation of steam and chemicals [3]. Various treatment technologies have been used for rendering industrial effluents into reusable form [5]. Paper mills in India adopt physico-chemical coagulation route followed by biological oxidation [6]. Bio-oxidation process is widely employed for reduction of dissolved organic matter from the effluents for its relative cost and ease of operation [7]. The final treated effluent produced by the biological processes is satisfactory for discharge into inland surface waters, as it is the case usually in India. However, further treatment is required to make it usable. Chemical treatment is relatively inexpensive but addition of chemicals further complicates waste management by creation of large sludge volume. Specific purification technologies such as flotation, evaporation, and membrane filtration are used to concentrate and fractionate spent liquor, remove color and treat bleach effluent [4,8–10]. Membrane filtration systems have become relatively simple and easy to operate as modular units. Membrane filtration such as micro-filtration (MF), ultra-filtration (UF), nano-filtration (NF), and reverse osmosis (RO) are being employed in the pulp and paper mills to close water loop. The reuse water quality can be met based on the degree of treatment employed [4].

A few points in consideration to wastewater treatment for recycle and reuse is that the treatment package must be easy to operate and recover resources from the wastewater. Maximum water reduction in the paper mills can be obtained through closing the cooling water loop [11]. Increased water use efficiency by modern process techniques is one of the major challenges faced by the paper industries using obsolete technologies in India. A mill in Finland achieved up to 75% reduction in freshwater consumption by simply changing feedstock, recycling white water from paper machine, Decker & screens and cooling water condensates by adopting latest techniques in screening, clarification and evaporation [12]. Studies from researchers working in this field have indicated water recovery from combined effluents to be prohibitively expensive. High grade water recovery is possible, if streams are segregated and target contaminants are eliminated. Some researchers have experimented on recovery of extraction (E) stage

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bleach plant effluent and concluded that UF and NF combination is well suited for treatment through membrane process because of its relative low volume and high molecular weight [13].

The present study aims to recycle treated effluent following chemical coagulation and membrane filtrations to reduce unit wastewater generation from the large scale integrated plant. Experiments were conducted at bench scale level to obtain streams suitable for recycling at economical costs.

2. Materials and methodology

2.1. The industry and water requirement

The mill is one of the largest integrated Kraft Sulphate pulp & paper mill in India with an installed capacity of 85,000 metric tons per annum. It is situated on the west banks of river Sone in central India [14]. The average paper production from the mill is between 250 and 300 MT per day of bleached white paper, tissue paper and poster paper made from bamboo and eucalyptus. The mill utilizes copious volumes of fresh river water for production (Table 1). The fresh water consumption in the mill ranged similar to a medium scale mill operating in the west. The consumption is between 36,000 ± 3000 m^3 day^{-1} basically for four process operations. The daily average flow on monthly basis has been collected from each section in the mill and a water/wastewater balance was made.

2.2. Effluent management

The effluents generated in the mill are segregated into Grades I, II, and III wastewaters based on the pollutant load from the mill. D-I, D-II, D-III and D-IV are various drains leading to respective effluent treatment plants (ETP). Wastewater stream from paper machine, condensates, turbine and evaporators, spray pond cooling water from contributes to Grade I. Grade II comprises effluent generated from stock preparation in the paper machine section, pilot and tissue paper plant, chlorination tower overflow and bleaching plant hypo section, including, chipper house wash water, drain water from sludge filter vacuum pumps and supernatant from lime sludge ponds (Drains I and III). Grade III comprises washings and screening operations from pulp section and caustic extraction stage of bleach plant (Drains II and IV). Wastewater stream from pulp section was brown in color due to the presence of lignin from pulp processing. The total effluent generated was between 28950 ± 2400$m^3$$day^{-1}$ out of which about 18200 ± 1565 m^3 day^{-1} is treated through Grade II ETP.

Table 1
Water consumption and wastewater generation in the Mill.

Section	Average flow, m^3/day
Water consumption	
Process	26,900 ± 1200
Cooling	3000 ± 1500
Boiler	1700 ± 200
Domestic	4400 ± 500
Total	36,000 ± 3000
Wastewater generation	
Chipper house	5000 ± 2045
Main paper machine	4500 ± 1283
Pilot plant and tissue plant	2400 ± 316
Soda recovery plant	2000 ± 112
Miscellaneous	800 ± 125
Total for drain no. I	14,700 ± 2598
Chlorine tower	3000 ± 245
Hypo bleach plant	5500 ± 142
Total for drain no. III	8500 ± 520
Total into the Grade II ETP	23,200 ± 220
Recycled back to chipper house	(−) 8000 ± 260
Supernatant from coal ash pond	(+) 3000 ± 345
Effective wastewater treatment in aeration ponds	18,200 ± 1565
Total into Grade III ETP (Drains II and IV)	10,750 ± 2750
Total wastewater treated	28,950 ± 2400

The industry has two full scale ETPs for treatment of Grades II and III wastewater. Grade I wastewater was not treated as it was clear and recycled for small operations inside the mill. The quantity was meager with less than 3% of total water consumption. Grade II effluent was treated through screens, primary clarifier followed by aerated lagoon (Fig. 1). Nutrients specifically urea and DAP are added prior to the aerated lagoon. The Grade III ETP was rendered through screens followed by primary clarifier, anaerobic ponds and aeration tanks. The treated effluent from the Grade III ETP is used for high rate evapo-transpiration systems [14].

2.3. Experimental design and selection criteria for delineation of feasible treatment scheme

Bench scale treatability studies were carried out to assess feasibility of recycling paper mill effluents. Criteria for selection of streams for feasibility of water reuse were based on flow (maximum value), pollutant load (minimum value), technological complications (minimum value), cost (minimum value) and residuals (minimum value). Delineation of recycling options is based on the management requirement to produce existing mill water standards used currently represented in Table 2. The major criteria adopted to recycle effluents through membrane treatment was lower pollutant concentrations specifically of BOD, COD, SS, silica, chlorine and hardness causing compounds. The studies were conducted on the individual and combined streams of the paper mill. Hourly samples were collected from the raw paper machine, clarified white water, pilot and tissue plants, chlorine tower, chipper house, soda recovery plant, hot water drains and coal ash pond and samples composited. Flow from various streams was assessed to make a wastewater balance on the volume of wastewater reaching Grade II ETP from various sections inside the mill (Fig. 1). The order of preference based on the above criteria is presented in the same table with least preference to the caustic extraction stage and pulp mill effluents. The streams selected for membrane filtration were paper machine section effluent, composite effluent I (paper machine section, tissue and pilot plant), composite effluent II (composite effluent I + settled coal ash pond effluent). Coal ash pond effluents are wastewater which used to transport ash from the mills power plant to the ash pond. The supernatant is sent to Grade II ETP for mixing. Membrane system was used to enhance the quality of treated effluent for recycle and meet the mill water quality standards. Mill proposed to increase production nearing 100% with the same freshwater input.

2.4. Sampling and analysis of effluents

Twenty-four hour composite samples were collected from various streams reaching the effluent treatment plant (ETP) and from different stages of effluent treatment. The samples were preserved at 4 °C and were analyzed after 24 hours for the parameters considered relevant to the effluent treatment and recycling. Analyses were carried out as per standard protocols for water and wastewater analysis [15]. The laboratory grade chemicals were used for the studies. Chemical reagents used were of analytical grade and purchased from Merck India Ltd. The analyses data have been arrived based on the average value of 2 samples. Samples have been collected from automatic samplers every hour and composited for 24 hours. The study was conducted over 1 week during winter, post monsoon and summer and the monthly daily average has been used for analysis characteristics.