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Cleaner Production Opportunity Assessment Study in SEKA Balikesir Pulp and Paper Mill

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ABSTRACT

This study aimed applying the Cleaner Production tolls to a Turkish pulp and paper mill, as the first time in the country, to introduce the concept as well as to provide a framework to future initiatives. To this purpose a comprehensive waste reduction audit was conducted to SEKA Balıkesir Pulp and Paper Mill. First, different audit schemes from different sources were examined and compiled leading to the methodology employed in this work. The audit covered water emissions and water usage. Then, the collected data were compared with international environmental performance indicators from other companies in USA, Canada, Australia, and Europe. This comparison provided the specific opportunities for improvement at different processes in the mill. For each opportunity determined from this approach, different waste reduction measures were analyzed and determined. Furthermore, the benefits of the identified waste reduction options were analyzed for increasing the production efficiency and achieving target raw effluent pollution loads of the mill.

Keywords: Cleaner Production, Waste Reduction, Pulp and Paper

INTRODUCTION

Industrial production without regard for environmental impacts has led to an increase in water and air pollution, soil degradation, and large-scale global impacts such as acid rain, global warming and ozone depletion. To create more sustainable means of production, there must be a shift in attitudes towards conventional waste management practices- moving away from control towards prevention. A preventive approach must be applied in all industrial sectors. Used in complement with other elements of sound environmental management, cleaner production is a practical method for protecting human and environmental health and supporting the goal of sustainability (Demirer, 2002).

The pulp and paper industry which produces commodity grades of wood pulp, primary paper and paper board products divides itself along pulping process lines: chemical pulping, mechanical pulping, and semi-chemical pulping. The products of the pulp and paper industry can also be categorized by the pulping process used in paper and paperboard production. (USEPA, 1995). Processes in the manufacture of paper and paperboard can, in general terms, be split into three steps: pulp making, pulp processing, and paper production. First, a stock pulp mixture is produced by digesting a material into its fibrous constituents via chemical, mechanical, or a combination of chemical and mechanical means. In the case of wood, the most common pulping material, chemical pulping actions release cellulose fibers by selectively destroying the chemical bonds in the glue-like substance (lignin) that binds the fibers together. After the fibers are separated and impurities have been removed, the pulp may be bleached to improve brightness and processed to a form suitable for papermaking equipment. At the papermaking stage, the pulp can be combined with dyes, strength building resins, or texture adding filler materials, depending on its intended end product. Afterwards, the mixture is dewatered, leaving the fibrous constituents and pulp additives on a wire or wire-mesh conveyor. Additional additives may be applied after the sheet-making step. The fibers bond together as they are carried through a series of presses and heated rollers. The final paper product is usually spooled on large rolls for storage (Smook, 1992).

The pulp and paper making industry is a very water intensive industry and ranks third in the world, after the primary metals and chemical industries, in terms of fresh water consumption. Historically, the pulp and paper industry has been considered to be a major consumer of natural resources (wood, water) and energy (fossil fuels, electricity) and a significant contributor of pollutant discharges to the environment (Berry et al., 1989; OTA, 1989; API, 1992; USEPA, 1993a; Thompson et al, 2001).

SEKA (Turkey Pulp and Paper Mills) Balıkesir Pulp and Paper Mill processes wood logs and purchased kraft for newsprint production. It is an integrated mill having steps of wood debarking and chip making, pulp manufacturing, pulp bleaching and paper manufacturing (SEKA, 1993). Flow diagram for the overall mill processes is given in Figure 1. The project design capacity of the mill is 100,000 tons/year. The average monthly newsprint production of the mill between October 2000 and September 2001, when this study was conducted, was 6,667 tons. (SEKA 1993 and 2001).

The objective of this study was to apply Cleaner Production concepts to a Turkish pulp and paper mill, as the first time, to introduce the concept as well as to provide a framework to future initiatives. To this purpose a comprehensive waste reduction audit was conducted to SEKA Balıkesir Pulp and Paper Mill. First, different audit schemes from different sources were examined and compiled leading to the methodology employed in this work. The audit covered water emissions and water usage. Then, the collected data were compared with international environmental performance indicators from other companies in USA, Canada, Australia, and Europe. This comparison provided the specific opportunities for improvement at different processes in the mill. For each opportunity determined from this approach, different waste reduction measures were analyzed and determined.

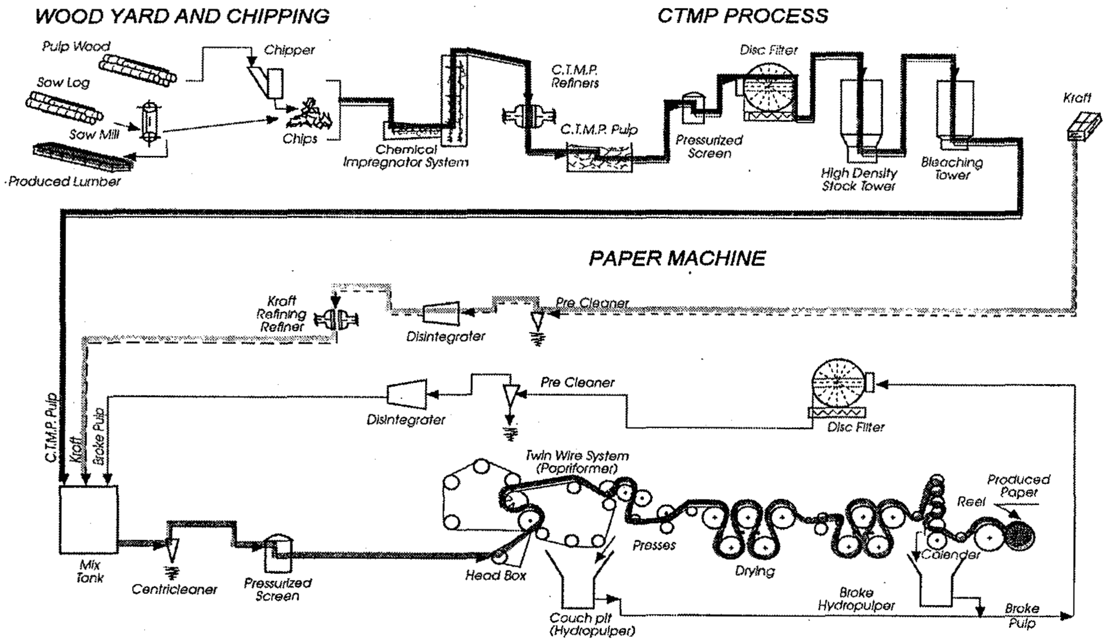

Figure 1. Process flow diagram of SEKA Balıkesir pulp and paper mill

METHODOLOGY

A waste audit procedure is a systematic toll used to identify the opportunities of Cleaner Production. The information from a waste audit can be a starting point for investigating pollution issues at any facility. Such an assessment of waste generation as well as raw material and energy consumption can highlight areas for potential intervention and provide a baseline for comparing subsequent increases or decreases in a specific waste stream. Based on the UNEP's Audit and Reduction Manual for Industrial Emissions and Wastes (1991) and other relevant literature (Edde 1984; Berry et al., 1989; UNIDO, 1993; UNEP, 1999; USEPA 1993a/1993b/1995), the methodology to be used in this study to identify waste streams and energy usage were developed and implemented. In order to conduct a purely descriptive audit in nature that provides a detailed picture of all the relevant waste streams, a material balance approach was utilized for the SEKA Balıkesir Pulp and Paper Mill.

Based on resource constraints, this study covered the main departments in SEKA Balıkesir Mill, namely, wood yard and chipping operations, CTMP process operations, and paper machine operations. It should be noted that departments like maintenance workshops can have significant environmental impacts (e.g. production of waste oils, leaking petroleum products storage tanks) and that landfills and other storage sites can produce contaminated leachate which can have an impact on groundwater as well as surface water. Generally, however, these departments have a minor role to play in cleaner production efforts, as compared to the production departments. Because of the availability of data, the audit concentrated on wastewater discharges arising from pulp and paper processes. Since SEKA Balıkesir Mill's own laboratory carries out many tests on wastewater analysis during their routine ISO 9002 quality assurance program.

Pulp and paper mills are very complex facilities composed of many departments, which are all interrelated in the production process. Consequently, when initiating a cleaner production assessment, it may be difficult to determine where to begin and how to compile the required information in such a way as to ensure that all relevant information is collected. For this reason a checklist was prepared and used to help in this process before conducting the waste audit. The checklist is based on the checklist prepared by SNC-LAVALIN (1998) for China – Canada Cooperation Project in Cleaner Production and modified to be used for SEKA Balıkesir Pulp and Paper Mill.

The adopted audit waste approach comprised of three phases; a pre-assessment phase for assessment preparation; a data collection phase to derive material balance; and a synthesis phase where the findings from the material balance are translated into a waste reduction plan. All the records (purchasing, production, etc.) for a 12-month period were used for the audit. The outline of the audit procedure is given in Table 1. Data gathered during Phase 2 was compared to environmental performance indicators (EPI) from different sources, which are specific for the process that SEKA Balıkesir Mill operates. Average and standard deviations of the indicators were calculated and presented. This comparison highlighted the areas, which needs particular attention for waste reduction measures.

Synthesis Phase represents the interpretation of the material balance generated in Phase 2 to identify process areas or components of concern. The arrangement of the input and output data in the form of a material balance facilitates the understanding of how materials flow through a production process. To interpret a material balance it is necessary to have an understanding of normal operating performance. For this purpose normalized pollution discharges per ton of end product were compared to the values in relevant literature in order to have an understanding of environmental performance of the mill processes. The material balance was used to identify the major sources of waste, to observe the deviations from the norms in terms of waste production, to identify areas of unexplained losses and to pinpoint operations which contribute to flows that exceed national or site discharge regulations. Based on the outcomes of this analysis, the determined waste reduction measures were classified as;

Table 1. The outline of the audit procedure

Phases	Steps
1. Preassessment	1. Assessment Focus and Preparation 2. Listing Unit Operations 3. Constructing Process Flow Diagrams
2. Material Balance: Process Inputs and Outputs	1. Determining Inputs 2. Recording Water Usage 3. Measuring Current Levels of Waste Reuse/Recycling 4. Quantifying Process Outputs 5. Accounting for Wastewater 6. Assembling Input and Output Information for Unit Operations 7. Evaluating and Refining the Material Balance
3. Synthesis	

Obvious waste reduction measures, including improvements in management techniques and house keeping procedures that can be implemented cheaply and quickly. Long-term reduction measures involving process modifications or process substitutions to eliminate problem wastes.

These cleaner production opportunities were discussed with the Mill Management or a superintendent assigned to our study by the management to select possible cleaner production initiatives for possible adoption.

RESULTS AND DISCUSSIONS

Because of the extent of the work, only the major findings and results will be summarized in this manuscript. However, all the details of the work can be found in Avsar (2001).

Data Collection

All the available information sources (raw material purchase records, product quantities, water usage and wastewater discharge data, etc.) as well as the checklists described in the Methodology Section and the personal interviews were used to gather all the available data for the mass balances.

Unit Operations

A site visit was performed and all process lines were examined. Detailed process descriptions are given Avsar (2001). The unit operations selected for analysis are pulp wood storage, debarking and chipping, pulping, pulp screening, bleaching, kraft repulping, and paper making. These operations are within the main sections of the mill, namely, wood yard and chipping operations, chemi thermo-mechanical pulp (CTMP) process operations, and paper machine operations (Figure 1).

Water Usage

Firstly, the water usage per unit production was calculated by the help of the data gathered in preliminary investigation of company data. Water usage per ton of newsprint produced was also calculated. According to year 2000 records, 3,865,000 m^3 of water was used. For the rest of the analyses, the data for the corresponding time interval (October 2000 – September 2001) was used for calculating annual consumptions and averages. Total water consumption for this period was found to be 4,428,900 m^3. The normalized water consumption per ton of paper produced is found to be 55.36 m^3/ton based on the total production of 79,998 tons of newsprint for the 12-month period investigated.

The process water for the mill was taken from Simav River located 14 km east of the mill site. Process water was treated in a primary treatment plant and pumped to the mill water reservoir (6,800 m^3) located at mill main site. Average and normalized water usage for individual steps of the process were reported in Table 2.

Process streams are being reused as much as possible through out the system. Most of the processes have multi-leveled stages for achieving maximum performance out of the input raw materials. Reused streams are discharged after at least two cycles of operation. 126,126 tones of condensate out of 290,621 tones of steam production were recycled in the year 2000 which makes 43.4%. Data obtained for year 2001 indicated a similar rate of condensate return, which is 44.2% (SEKA, 2001).

Table 2. Water consumptions of individual process steps

Unit Operations	m^3/year (annual consumption)	m^3/ton of pulp produced (AD)	m^3/ton of paper produced
Wood Yard and Chipping	300,000	4.22	3.75
Pulping	1,100,000	15.47	13.75
Kraft Repulping	400,000	5.63	5
Paper Making	1,565,000	22.01	19.56
Subtotal	3,365,000	47.32	42.06
Other Services	1,063,900	14.96	13.30
Total	4,428,900	62.28	55.36

Source: SEKA (2001)

Power Consumption

The power consumptions per individual processes and normalized power consumption per ton of products for the study period are tabulated in Table 3.

Table 3. Annual power consumptions per ton of product

Unit Operation	Annual Power Consumption (kWh)[1]	Power Consumption per ton of AD pulp produced (kWh/ton)	Power Consumption per ton of paper produced (kWh/ton)
Wood Yard & Chipping	1,829,094	25.7	22.9
CTMP process	181,415,440	2,551.2	2,267.8
Paper Machine	30,759,466	432.6	384.5
Other Services	3,392,720	47.7	42.4
Total	217,396,720	3,057.1	2,717.5

(1) Wastewater treatment plant power consumption, which is 2,000,000 kWh per year, is distributed among the unit operations according to their percent share in overall consumption

Source: SEKA (2001)

Process Inputs

Based on the data gathered at the pre-assessment step, annual raw material consumption data for individual process steps was determined and tabulated in Table 4. Total news print produced for the study period (12 months; October 2001 – September 2001) was 79,998 tons. By using this figure and the data in Table 2, average normalized raw material consumptions per ton of newsprint produced were calculated and also presented in Table 4.

No significant handling losses were observed except for saw dust in the wood yard. Saw dust that is going to be burnt in hogged fuel boilers for power and steam generation were stored and transported in an open area. This open-air storage and transportation of saw dust results in significant material losses. Mr. Töre, head of CTMP department, stated that these losses were about 1% of the total wood that makes 2,223 m^3 per year (personal interview, 29.05.2001).

Table 4. Raw material consumptions for the mill

Raw Materials	Unit	Wood Yard & Chipping	CTMP Process	Paper Machine	Power Supply & Heating	Total Consumpsion	Total Normalized Consumption*
Pulpwood	M^3		177,000			216,666	1,549
	Ton		123,900				
Kraft (90% dry)	Ton			12,778		12,778	160
Aluminum Sulfate	ton		2,300	350	150	2,800	35
Sodium Hydroxide	ton		1,775	85		2,000	25
Lime	ton				1,000	1,000	13
Soda Ash	ton				380	380	5
Sulfuric Acid	ton				70	70	1
Hydrochloric Acid	ton				70		
Hydrogen Peroxide	ton		2,000			2,000	25
Sodium Silicate	ton	10	1,100			1,110	14
EDTA or DTPA	ton		320			320	4
Sodium Metabisulfite	ton		2,240			2,240	28
Sodium Dithionite	ton		320			320	4
Defoamer	ton		32	80		112	1

* kg/ton of paper produced
Source: SEKA (2001)

Process Outputs

The process outputs from each of mill's unit operation were listed in Table 5. These outputs were quantified in following sections.

Process wastewater flows were obtained from mill's records. Main waste streams were quantified by using the existing ultrasonic flow meters. Separate quantification of sub-streams were not carried out since it would require many sampling points which will need additional specific sampling and monitoring equipment. Wastewater streams were grouped into four; Wood yard and chipping operations (pulp wood storage, debarking and chipping), CTMP process operations (pulping, pulp screening, pulp washing and thickening, bleaching, kraft repulping), Paper machine operations (wet end operations), and Other services (domestic effluents, washing etc.).

Table 5. Process outputs

Unit Operations	Waste Water	By-Product / Waste Reuse
Pulp Wood Storage	Water used in handling and moisturizing	
Debarking and Chipping	Log pond make-up water	Bark, Sawdust
Pulping	Chip washer drain, Liquid from chemical impregnator, Liquor spills	
Pulp Screening	Spills and reject losses, "White waters" from pulp screening	Pulp rejects
Pulp Washing and Thickening	"White waters" from pulp thickening and cleaning	
Bleaching	Bleach plant washer filtrates, spills	
Kraft Pulping	Kraft Pre – cleaner screenings	
Paper Making	Water collected as pulp dries, spills	Paper rejects

EPIs for wood yard and chipping operations and CTMP process operations in the literature are based on production of air dried (90% solids) pulp (ADP). For this reason, pulp production is considered in correlating pollution loads of wood yard and chipping operations and CTMP process operations per ton of pulp and paper produced. Net paper production is considered only when investigating the pollution loads of paper machine operations. Wastewater generation rates and pollution loads for selected water quality parameters are tabulated in Table 6.

A preliminary material balance of data associated within the mill was drawn up on an overall input/output material basis (Figure 2). It was decided that the material balance is adequate (within 5-10% as stated in Hageler Bailly Consulting Inc., 1995) for the mill as a whole.

Table 6. Wastewater flow rates and pollution loads from different unit operations of the mill

Unit Operations	Flow		pH	BOD_5		COD		TSS	
	m^3/year	m^3/ton		mg/L	kg/ton	mg/L	kg/ton	mg/L	kg/ton
Wood Yard & Chipping	297,000	4.2	7	556	2.3	1,275	5.3	7,150	29.9
CTMP Process	1,376,000	19.4	5.5	2,440	47.2	9,065	175.4	1,309	25.3
Paper Machine	1,580,000	19.8	6.5	641	12.7	1,116	22.0	645	12.7
Total	3,253,000	40.7	6.5	1,197	48.7	3,791	154.2	1,241	50.5

Synthesis

In this synthesis stage, results obtained in the previous section were compared to EPIs stated in the relevant literature. The definition and selection of EPIs is still at an early stage, but the use of indicators is increasing, both for tracking trends in pollution and other environmental issues on a large scale (national or regional) and for monitoring industrial projects. As investments in Cleaner Production Assessments grow, it becomes increasingly important to develop quantitative measures of the effect of such investments on the environment.

Inputs	***Ton/annum***
Wood Logs	151,666
Kraft	12,778
Chemicals	12,352
Water	3,365,000
Steam	186,800
Total	***3,728,596***

⇓

Overall Mill Operations (Debarking and Chipping, Pulping, Paper Machine)

⇓

Outputs	***ton/annum***
Newsprint	79,998
Bark and Saw Dust to Hog Fuel Boilers	18,447
Bark and Saw Dust lost	1,523
Wastewater	3,253,000
Fiber loss	3,750
Steam Exhausted	200,000
Total	***3,556,718***

Figure 2: Mass balance for overall mill operations

EPIs and benchmarks of cleaner production enable comparisons of performance between industry sectors and industries in the same sector. The data obtained in material balance section was compared with EPIs and benchmarks found in technical literature for integrated mills using CTMP process in order to target problem wastes (Table 7). Having tabulated the EPIs and benchmarks from various sources for the three main process sections of the SEKA Balıkesir Mill, its performance was compared to the average values of these indicators. After comparing the environmental performance of the mill with that of relevant literature, and thus, determining the existing potential for the improvement, cleaner production opportunities for each process section (wood yard and chipping operations, CTMP process operations, and paper machine operations) were discussed below:

Wood Yard and Chipping Operations

Actual water consumption and wastewater generation rates are significantly higher than target pollution loads. Total suspended solids load is extremely high compared to the target (Table 7). Cleaner production opportunities for reducing these extreme levels were discussed in detail with Mr, Mehmet Öçal, Mill General Manager and Mr. Kaptan Töre, Head of CTMP Department on 03.10.2001. Cleaner production options for wood yard and chipping operations are discussed and summarized below:

Recycle of Log Flume Water

Log flumes are used at SEKA Balıkesir Mill to transport wood from log piles to debarker and chippers. The water used to convey the logs can be recycled, with fiber and bark being recovered and burned in the "hogged fuel" boiler for heat recovery. Alternatively, or in addition, treated wastewater can be used as makeup for the log flume.

The practice of log flume water recycle is common among mills that use log flumes. Costs of developing an appropriate recycle system may be in the range of $100,000 to $500,000 (USEPA, 1993a). Payback period of this investment is 1-2 years (UNEP, 1999). Recycle of log flume water will reduce the discharge of BOD, and TSS, as well as conserve water. Maximum waste reductions that have been previously estimated by USEPA (1982) based on data from made installations for wood yard and chipping operations are tabulated in Table 8 (USEPA, 1982).

Table 7. Comparison of pollution loads with EPIs

Parameter	(a)	(b)	(c)	(d)	(e)	Mean	St. Dev.	SEKA Balıkesir Mill
Wood Yard & Chipping Operations								
Water Consumption (m^3/ton of ADP produced)		1.5	1.5	1.5	1.0	1.38	0.25	4.2
Power Consumption (kWh/ton of ADP produced)					20.0	20.00	0.00	25.7
BOD_5 (kg/ton of ADP produced)	2.3	1.0	1.0	1.0	1.0	1.26	0.58	2.3
COD (kg/ton of ADP produced)		4.2	4.0	5.0	4.0	4.30	0.48	5.3
TSS (kg/ton of ADP produced)	5.0	4.0	2.0	2.0	3.0	3.2	1.30	29.9
Wastewater Generation (m^3/ton of ADP produced)		1.0	1.0	1.0	0.8	0.95	0.10	4.2
CTMP Process Operations								
Water Consumption (m^3/ton of ADP produced)		15.0	12.0	15.0	15.0	14.25	1.50	21.1
Power Consumption (kWh/ton of ADP produced)					2100.0	2100.00	0.00	2551.2
BOD_5 (kg/ton of ADP produced)	11.3	35.0	30.0	25.0	40.0	28.26	11.00	47.2
COD (kg/ton of ADP produced)		100.0	90.0	100.0	80.0	92.50	9.57	175.4
TSS (kg/ton of ADP produced)	6.8	10.0	8.0	10.0	7.0	8.36	1.56	25.3
Wastewater Generation (m^3/ton of ADP produced)		15.0	12.0	15.0	15.0	14.25	1.50	19.4
Paper Machine Operations								
Water Consumption (m^3/ton of paper produced)		15.0	17.0	17.0	15.0	16.00	1.15	19.6
Power Consumption (kWh/ton of paper produced)					230.0	230.00	0.00	384.5
BOD_5 (kg/ton of paper produced)	3.0	2.0	3.5	3.5	3.0	3.00	0.61	12.7
COD (kg/ton of paper produced)		14	15	13.5	15	14.38	0.75	22
TSS (kg/ton of paper produced)	3.0	3.0	4.0	4.0	4.0	3.60	0.55	12.7
Wastewater Generation (m^3/ton of paper produced)		15.0	17.0	17.0	15.0	16.00	1.15	19.8

(a) Bond and Straub, 1972; (b) Aquatech, 1997; (c) USEPA, 1993b; (d) World Bank, 1997; (d) UNIDO, 1993

Storm Water Management

During the site visit it was noted that saw dust existing in the wood yard was contributing to the effluent channel. The impact of storm water runoff and wind is significant in this contribution. At the wood yard, the runoff from wood and chip storage and processing areas is of greatest concern, as these streams may contribute substantially to BOD_5 and TSS loadings (USEPA, 1993a).

Options for reducing storm water impacts on receiving waters include modifying wood yard operations to reduce storm run-off (i.e., moving operations inside), and installing curbing, diking, and drainage collection for storm water from chip piles and wood processing areas. Storage and treatment of collected storm water would be required. Collected storm water can be transported to the wastewater treatment facility, which could effectively remove the pollutant of concern. USEPA (1993a) estimated up to 4 kg TSS reduction per ton of ADP produced (Table 8). Total waste reductions estimated for implementation of both of these cleaner production options are summarized also in Table 8.

Table 8. Summary of waste reduction estimates for wood yard and chipping operations

Parameter	Max. Estimated Decrease by		Max. Total Estimated Decrease
	Recycle of Log Flume Water	Storm Water Management	
Water Consumption (m^3/ton of ADP produced)	3	-	3
BOD_5 (kg/ton of ADP produced)	2	-	2
COD (kg/ton of ADP produced)	3	-	3
TSS (kg/ton of ADP produced)	11.5	4	15.5
Wastewater Generation (m^3/ton of ADP produced)	3	-	3

<u>CTMP Process Operations</u>

Pollution loads for the parameters presented in Table 7 in the raw effluent from CTMP process operations are significantly high. Cleaner production opportunities for reducing these extreme levels were discussed in detail with Mr Mehmet Öçal, Mill General Manager and Mr Kaptan Töre, Head of CTMP Department on 03.10.2001 as it was made for wood yard and chipping operations. Cleaner production options determined for the CTMP process operations are presented below:

Raw Material Selection

Suspended solids concentration in effluents of pulp and paper mills is an important factor since it is directly proportional to the loss of main raw material, the furnish. Chips that are going to be used in pulp processing should be in sufficient quality and size as discussed in earlier sections. The most important factor that is affecting the chip quality is the wood itself.

Pinus brutia and pinus nigra type pulpwood are resulting in very fine fibers and obtained chips are not in desired quality. Since those types of woods are purchased locally, they are the primary raw materials used in manufacturing. Imported pulpwood usage was reported to decrease fiber losses by 15 to 20% and also to decrease the kraft usage by 25%. The corresponding maximum waste reductions estimated for wood yard and chipping operations are tabulated in Table 9 (SEKA, 1993).

Improved Chipping and Screening

Improved chipping would also be a possibility for reducing fiber losses. The purpose of chipping is to reduce the logs to a smaller size suitable for pulping. In the chipper installed at SEKA Balıkesir Mill, logs are fed into a chute where they contact a disc outfitted with a series of radially mounted blades. The blades project about 20 mm from the disc. Chip uniformity is extremely important for proper circulation and penetration of the pulping chemicals, hence considerable attention is paid to operational control and maintenance of the chipper. Chips between 10 and 30 mm in length, and 2 to 5 mm in thickness, are generally considered acceptable for pulping.

The chipped wood is passed over a vibrating screen that removes undersized particles (fines) and routes oversized chips for rechipping. Normally, fines are burned with bark as hogged fuel, although they may also be pulped separately in specialized "sawdust" digesters. In SEKA Balıkesir Mill, chips are segregated only based on chip length.

Chip thickness screening has become important as mills realize the need to extend delignification and reduce bleach plant chemical demands. Both absolute chip thickness and thickness uniformity have a significant impact on delignification, since the cooking liquor can only penetrate the chip to a certain thickness (Tikka et al., 1992). Thin chips are easier to cook to lower kappa numbers. Uncooked cores from over-thick chips will lower the average kappa reduction of a cook and contribute to higher bleaching chemical demands. To improve thickness uniformity, many mills are now adopting screening equipment that separates chips according to thickness (Strakes and Bielgus, 1992). Chips that exceed the maximum acceptable thickness are diverted to a chip slicer that cuts them radially and reintroduces them to the screening system. Costs for chip thickness screening and reprocessing of between $0.4 and $2 million have been cited for new installations (USEPA, 1992). Payback period for this investment have been cited to be 2-3 years (UNEP, 1999). Maximum estimated waste reductions for improved chipping and screening option are tabulated in Table 9 (Strakes and Bielgus, 1992).

Extended Delignification

The amount of chemicals required in the bleach plant to bring the pulp to the target brightness level is directly related to the residual lignin content of the pulp. The mill can reduce the bleaching chemical demands, and subsequent environmental effects by adopting techniques that reduce the residual lignin content. Over the last decade, methods and equipment have been developed that allow the pulp cooking time to be extended, enabling further delignification to occur before the pulp moves on to the bleach plant (USEPA, 1993a).

The ability to extend the cooking process without impacting pulp quality has been achieved by applying principles developed by the Swedish Forest Products Research Institute (STFI) in the late 1970s (Hartler, 1978). The technique involves charging the cooking chemicals at several points throughout the cook. This levels out the alkali profile in the pulp, permitting more lignin to be dissolved in the latter stages of the process. By attaining greater control, the delignification reaction can be extended, and the lignin content of the pulp reduced by between 20 and 50 percent compared to conventional digesters.

By splitting the addition of cooking liquor and improving liquor circulation and mixing, modified cooking processes level out the alkali concentration not only from the beginning to the end of the cook but also throughout the length of the digester. The more uniform cooking of chips throughout the digester helps maintain pulp yield, (fewer under and over cooked chips), and leads to easier bleachability and reduced bleaching chemical demand. Extended delignification has been shown to reduce the kappa number (USEPA, 1993a).

Reductions in conventional pollutants such as BOD_5, COD, and color have also been widely realized. According to Heimburger et al. (1988), extended cooking reduced kappa by 22 percent, while BOD_5 and color declined by 29 and 31 percent, respectively. Total cost of the modification of the CTMP process have been estimated to be between \$1.5 and \$2 million (USEPA, 1993a). Payback period for this modification have been estimated to be 2 years

(UNEP, 1999). Maximum estimated waste reductions for the improved chipping and screening option are tabulated in Table 9 (Heimburger et al., 1998).

Table 9. Summary of waste reduction estimates for CTMP process operations

Parameter	Max. Estimated Decrease by				Max. Total Estimated Decrease
	Improved Raw Material Selection	Improved Chipping & Screening	Extended Delignification	Spill Control	
Water Consumption (m^3/ton of ADP produced)	3	-	-	3	6
BOD_5 (kg/ton of ADP produced)	9	11	13	5	38
COD (kg/ton of ADP produced)	28	20	32.5	20	100.5
TSS (kg/ton of ADP produced)	6.5	8	-	5	19.5
Wastewater Generation (m^3/ton of ADP produced)	3	-	-	3	6

Pulping Liquor Management, Spill Prevention, and Control

Many spills were observed through out the pulping operations. Most of them were resulting from improper house keeping, damaged valves, and leakages from damaged sealing gaskets of pumping equipment. These spills were resulting in excessive pollution loads and raw material losses. Spills and intentional diversions from the pulping areas are a principal cause of upsets in biological treatment systems. Pulping liquor losses increase the need for pulping liquor make-up chemicals.

A management program combined with engineered controls and monitoring systems, can prevent or control pulping liquor losses. These efforts should be both proactive to prevent pulping liquor losses and reactive to control spills after they have occurred.

When spills are detected in the key process sewers the flow can be diverted to either the spill tank or the spill lagoon. Specific concentrated flows, like cooking and bleaching chemicals could be routed directly to the spill tank. The contents of the spill tank are put back into the process. The weak spills in the lagoon are treated in the effluent treatment facility (Edde, 1984).

Mills with effective pulping liquor spill prevention and control programs have instituted a combination of these practices to substantially eliminate rich white water losses. It has been reported that the practical maximum reduction in BOD_5 raw wastewater loading that can be attained from spill prevention is 5 kg per ton of AD pulp, where as reductions in COD loadings are up to 30 kg per ton of AD pulp (USEPA, 1993a). The maximum estimated waste reductions for improved chipping and screening option are tabulated in Table 9 (USEPA, 1993a).

Paper Machine Operations

Total suspended solids levels and BOD_5 loadings in the raw effluent from paper machine operations are extremely high as it is in wood yard and chipping operations. Cleaner production opportunities for reducing these extreme levels were discussed in detail with Mr Mehmet Öçal, Mill General Manager and Mr Kaptan Töre, Head of CTMP Department on 0.10.2001 as it was made for wood yard and chipping operations and CTMP process operations. The determined cleaner production options for paper machine operations are presented below:

Additional Vacuum Extraction Tanks

Papriformer application in paper machine uses centrifugal force for dewatering of paper sheet. This is resulting in high fine fiber losses due to the centrifugal force (SEKA, 1993). Mill management suggested that additional vacuum extraction tanks that would be installed between formation and couch rolls could decrease the fine fiber losses up to 25%, which results in BOD_5 load reduction of 7 kg per ton of paper produced and 8 kg per ton of paper produced in TSS loading (USEPA, 1993a). Renewing of the headbox and wire section would also let the mill to operate at higher machine speeds, thus having a higher production capacity (Smook, 1992). Mill management stated that this investment would cost $0.6 million. Payback period is estimated to be 22 months (SEKA, 2001). Maximum estimated waste reductions for improved chipping and screening option are tabulated in Table 10 (USEPA, 1993a).

Reducing Seal Water Utilized in on the Vacuum Pumps

In a rational scheme for closure, the first logical step is to use rich, white water from the wire pit and couch pit in as many applications as possible. This would include use as dilution water for the pulpers for all stock systems and for consistency regulation in all stock systems. The second step would be to make maximum use of save all clarified clear water. This should be used for all machine showers, which can tolerate this quality water. The water quality probably adequate for wire showers, wire knock-off showers, and roll showers. These shower applications presuppose a well-controlled save all producing high quality clarified effluent (Casey, 1980).

One possibility for handling the large volume of seal water utilized on the vacuum pumps would be to use all clarified water in this application. The Nash Company (Casey, 1980) recommends the following quality: abrasion less than 50 mg/L, soft fibrous suspended matter less than 360 mg/L, pH less than 5.5, total dissolved solids less than 500 mg/L, and total hardness less than 200 mg/L. Because a large volume of water is involved, it seams reasonable to consider creating a separate recirculation system for the vacuum pumps. The basic idea in a recirculation system is to collect the seal water from all pumps in pit located below the pumps, cool this water by some means and return the water to the pumps. One alternative recommends using fresh cold water on the high-vacuum pumps and then using this water to provide sealing water for the lower vacuum pumps. Another alternative recommends putting the pumps in a recirculation system and the temperature of the recirculated water is controlled by bleeding in cold fresh water at rate, which is thermostatically controlled. The maximum estimated water consumption reduction for reducing seal water utilized in the vacuum pumps option is tabulated in Table 10 (Casey, 1980).

Table 10. Summary of waste reduction estimates for paper machine operations

Parameter	Max. Estimated Decrease by				Max. Total Estimated Decrease
	Additional Vacuum Extraction Tanks	Reducing Seal Water Utilized in Vacuum Pumps	Reducing Fresh Water Usage in Felt Showers	by Replacing of Gland Seals	
Water Consumption (m^3/ton of paper produced)	-	1	1	0.5	2.5
BOD_5 (kg/ton of paper produced)	7	-	-	-	7
COD (kg/ton of paper produced)	15	-	-	-	15
TSS (kg/ton of paper produced)	10	-	-	-	10
Wastewater Generation (m^3/ton of ADP produced)	-	1	1	0.5	2.5

Reducing Fresh Water Usage in Felt Showers

It would be ideal to use saveall-clarified water in felt showers. However, this is a sensitive application requiring consistently high quality water (Casey, 1980). The best method for handling felt shower water is to minimize through use of high pressure, low volume showers.

Substantial water savings are possible with application of these devices (Morrissey, 1980). A reduction of up to 94% in shower water volume is possible. The maximum estimated water consumption reduction for reducing fresh water usage in felt showers option is tabulated in Table 10 (Casey, 1980).

Replacing of Gland Seals and Collection of Cooling Water

Two of the major water consuming items of the paper machine are gland seals and cooling water. The cooling water is best handled by creating a clear water sewer for the mill in which all uncontaminated cooling water is collected and discharged untreated since it contains only thermal energy as a contaminant. Many gland seals can be replaced by mechanical seals. This would result in a fresh water reduction of 1 m^3 per ton of paper produced. The maximum estimated water consumption reduction for reducing seal water utilized in the vacuum pumps option is tabulated in Table 10 (Casey, 1980).

Power Consumption

Normalized power consumptions of the individual processes are higher than the corresponding environmental performance indicators as it was presented in Table 7. During the site visit it was observed that many of the pipe insulations of the process steam lines were damaged. Proper maintenance of these insulations could reduce the normalized power consumptions. Mr Kaptan Tore, Head of CTMP Department stated on 05.05.2001 during the on-site visit that energy savings up to 10 percent could be achieved by proper maintenance of hot water and steam pipeline insulations. Such renewal requires $0.1 million with a payback period of 14 months (SEKA, 2001). Estimated reductions in normalized power consumptions are presented in Table 11.

Table 11. Estimated reductions in power consumptions of individual operations by proper maintenance of pipe insulations

Unit Operation	Actual Normalized Power Consumption (kWh/ton of product)	Estimated Decrease by Proper Maintenance of Pipe Insulations (kWh/ton of product)
Wood Yard and Chipping Operations	25.7	2.6
CTMP Process Operations	2,551.2	255.1
Paper Machine Operations	384.5	38.5

CONCLUSIONS

The CP options proposed for the SEKA Mill as the output of this study were identified basing on the pulp and paper sector cleaner production case studies from various countries as well as the constraints stated by the mill management. Furthermore, the mill management evaluated and approved these options as "viable". According to the results of the Cleaner Production Opportunity Assessment Study conducted at the SEKA Balıkesir Mill;

- Normalized water consumptions, power consumptions, wastewater generation rates, raw effluent pollution loads per ton of pulp and paper produced in SEKA Balıkesir Mill do not achieve the target values of EPIs recommended and adopted worldwide for the pulp and paper mills running the similar process (Table 7).

- Based on the waste audit carried out, several cleaner production options for wood yard and chipping operations (recycle of log flume water and storm water management), CTMP process operations (improved raw material selection, improved chipping and screening, extended delignification, and pulping liquor management, spill prevention, and control), and paper machine operations (installation of additional vacuum extraction tanks, reducing seal water utilized in the vacuum pumps, reducing fresh water usage in felt showers, replacement of gland seals by mechanical ones) were suggested for the mill. These options which have relatively short payback periods would reduce water and energy consumptions as well as COD, BOD and TSS loads from the mill significantly (Tables 8-10).

- Finally, upon adoption of the CP options proposed in this study, SEKA Balikesir Mill could achieve the target environmental performances for an integrated pulp and paper mill running CTMP process for pulping, enhance the performance of its wastewater treatment plant, and acquire a baseline for the Mill's planned ISO 14000 system implementation.

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