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United States Agency for International Development

**POLLUTION PREVENTION DIAGNOSTIC**
**TEXTILE DYEING PLANT**

Final Report

Prepared for:

Haggler Bailey Consulting, Inc.
1530 Wilson Blvd., Suite 900
Arlington, VA 22209-2406

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1996
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ACKNOWLEDGMENTS

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The pollution prevention audit/assessment reported on herein was conducted by a team of EP3 and industry representatives. The primary purpose was to assist industry or facility management in creating a sustainable pollution prevention and waste minimization program. This report presents information from the first step in the process; a base line assessment and a definition of actions which can be taken to prevent pollution, improve efficiency and pay back any required investments.

The overall EP3 program in the countries in which EP3 has activities includes a wide variety of activities including audit/assessments, information dissemination, training and small scale demonstrations. These country programs are all designed to create the conditions in the country which will assure the continuation of urban and industrial pollution prevention and establish locally sustainable pollution prevention programs.

This report was prepared for Haggler Bailey Consulting, Inc. by Jill Watz, Strategic Environmental Management Consulting, 1765 Willard Street, NW, Washington DC 20009 and Allen B. Ward, Hydrosience, Inc., 1551 Sea Island Parkway, St. Helena Island, SC 29920-9600.
CHAPTER 1
EXECUTIVE SUMMARY

A pollution prevention assessment of the Plant X dyeing operations was conducted between March 25 and 27, 1996, in City X, Country X. A pre-assessment study was conducted by the Country X EP3 team two months prior to this assessment. A total of seventeen recommendations are provided in this report that will assist Plant X reduce environmental effluents, conserve energy, reduce chemical use, increase productivity and reduce projected operating costs for future water treatment requirements.

The first seven recommendations summarized in Table 1 provide a total estimated fuel savings of $65,600/year; an estimated chemical savings of $5,500/year, a reduced electricity savings of $3,700/year and a projected avoided wastewater treatment investment of $235,000 and an avoided annual operating cost of $23,500/year. The total capital investment to achieve these savings is estimated to be less than $30,000. Two recommendations provide capital investment for energy savings with paybacks of less than 4 years. The remaining eight recommendations provide potential pollution prevention options that could result in cost savings but, insufficient information was available to determine the cost and savings. These recommendations are considered valuable and certainly worth further study by the facility to evaluate potential savings.

Note, that many discrepancies in information received from facility operators during the pre-assessment and assessment interviews were identified. Unfortunately, the facility was unable to validate the majority of the data provided with standard measurement calibrations and operating information. All recommendations are based on the what appeared to be the most reasonable data and good engineering assumptions used for other similar types of operations. The authors strongly recommend that the facility independently review the assumptions, make appropriate measurements, as suggested, and re-evaluate cost and savings estimates based on better qualified data.
## TABLE 1
### SUMMARY OF POLLUTION PREVENTION OPPORTUNITIES

<table>
<thead>
<tr>
<th>Pollution Prevention Recommendation</th>
<th>Benefit</th>
<th>Cost to Implement</th>
<th>Estimated Savings</th>
<th>Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establish standard operating procedures</td>
<td>Is essential to implementation of existing recommendations and further evaluation of process improvements.</td>
<td>US$2,000</td>
<td>Indeterminate</td>
<td>Indeterminate</td>
</tr>
<tr>
<td>Reuse rinse water from latter stages of wash operation</td>
<td>Reduce water use by 163 m³/day.</td>
<td>US$2,000</td>
<td>US$2,400 per year in well water pumping, US$100,000 and 10,000 in future WWTF capital and annual operating costs, respectively.</td>
<td>10 months</td>
</tr>
<tr>
<td>Reuse final overflow from bleach-washing in desiring.</td>
<td>Reduce water use by 100 m³/day, chemical cost savings, energy savings, better fabric cleaning.</td>
<td>US$20,000</td>
<td>US$2,000 per year in chemical costs, US$37,000 per year in energy costs, future WWTF capital and annual operating savings of US$75,000 and 7,500, respectively.</td>
<td>6 months</td>
</tr>
<tr>
<td>Optimize desire operation.</td>
<td>Reduce water use by 50 m³/day, possible chemical savings.</td>
<td>Further study needed, most improvements require minimal cost</td>
<td>US$800 per year in pumping costs, US$35,000 and 3,500 in future WWTF capital and annual operating costs, respectively.</td>
<td>Immediate</td>
</tr>
<tr>
<td>Optimize bleaching operation.</td>
<td>Slightly reduce water use and caustic discharge, chemical cost savings.</td>
<td>US$2,000</td>
<td>US$3,500 per year in chemicals.</td>
<td>7 months</td>
</tr>
<tr>
<td>Optimize washing operation.</td>
<td>Reduce water use by 37 m³/day.</td>
<td>Further study needed, most improvements require minimal cost</td>
<td>US$500 per year in well water pumping, US$9,700 per year in energy costs, US$25,000 and 2,500 in future WWTF capital and annual operating costs, respectively.</td>
<td>Immediate</td>
</tr>
</tbody>
</table>
## Executive Summary

<table>
<thead>
<tr>
<th>Pollution Prevention Recommendation</th>
<th>Benefit</th>
<th>Cost to Implement</th>
<th>Estimated Savings</th>
<th>Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Optimize Print Operation</td>
<td>Reduce energy consumption and pigment loss</td>
<td>$2,000</td>
<td>$18,900 reduced diesel cost</td>
<td>&lt; 1 month</td>
</tr>
<tr>
<td>8. Install vacuum slot de-watering device</td>
<td>Reduce energy consumption by reducing water load to dryers</td>
<td>$35,000-$40,000</td>
<td>$10,500 per year</td>
<td>&lt; 3.5 years</td>
</tr>
<tr>
<td>9. Replace old motors with efficient motors</td>
<td>Reduce electrical consumption</td>
<td>$50,000</td>
<td>$14,000 per year</td>
<td>4 years</td>
</tr>
<tr>
<td>10. Improve dye bath chemical mixing</td>
<td>Reduce dye spotting</td>
<td>$200</td>
<td>Indeterminate</td>
<td>Indeterminate</td>
</tr>
<tr>
<td>11. Maximize dye exhaustion</td>
<td>Reduce dye waste.</td>
<td>None.</td>
<td>Indeterminate, further study needed.</td>
<td>Indeterminate</td>
</tr>
<tr>
<td>12. Apply finish in dry operation.</td>
<td>Reduce finish waste.</td>
<td>TBD.</td>
<td>Indeterminate, further study needed.</td>
<td>Indeterminate</td>
</tr>
<tr>
<td>14. Evaluate process water softening</td>
<td>Reduce detergents required, reduce water use, minimize fabric spotting. Increase boiler efficiency, reduce fuel costs</td>
<td>US$100,000</td>
<td>US$9,000 in chemicals, possible increased profit margin in other markets.</td>
<td>Indeterminate</td>
</tr>
<tr>
<td>15. Institute a water monitoring program</td>
<td>Essential to strategic planning.</td>
<td>US$6,000</td>
<td>Indeterminate (potential benefits could be great)</td>
<td>Indeterminate</td>
</tr>
<tr>
<td>16. Evaluate a computer-based color-matching system.</td>
<td>Less chemical waste</td>
<td>US$10,000</td>
<td>Indeterminate, further study needed.</td>
<td>Indeterminate</td>
</tr>
<tr>
<td>17. Substitute chemicals/change processes (when appropriate)</td>
<td>Improved environmental compliance, reduced wastewater treatment burden</td>
<td>Indeterminate, further study needed.</td>
<td>Indeterminate, further study needed.</td>
<td>Indeterminate</td>
</tr>
</tbody>
</table>
CHAPTER 2
OBJECTIVES

2.1 ASSESSMENT OBJECTIVES

The objective of this assessment was to identify pollution prevention options for the Plant X textile dyeing facility located in City X, Country X. In general, the assessment focused on identifying cost effective opportunities to reduce raw materials, water usage, and energy usage. The facility does not appear to handle any toxic or hazardous materials. Suggested recommendations provide reasonable cost payback and/or improve the productivity and economic viability of the company while at the same time reducing the impact on the local environment.

2.2 REPORT OBJECTIVES

This report has three objectives: 1) to assist the Plant X facility cost effectively reduce the environmental impact of textile dyeing operations and implement procedures to continuously improve operations; 2) provide guidance to in-country EP3 project staff to assist Plant X with implementing and measuring results; and 3) assist in disseminating general textile pollution prevention information to similar facilities in Country X.

2.3 REPORT LIMITATIONS

The assessment focuses on the technical aspects of pollution prevention and is not intended to be a comprehensive evaluation of the safety and health impacts or considerations of the plant's operation. The assessment also does not address general business and management practices such as accounting procedures, data gathering, and data analysis. The analysis provided herein is based solely on the information obtained from the facility personnel participating in this review. This report provides the details on how to achieve and maintain pollution prevention changes at the facility and should serve as a first step in developing a sustainable pollution prevention program at the facility; and, to provide information that will help similar facilities.
CHAPTER 3
BACKGROUND INFORMATION AND
PROCESS DESCRIPTION

3.1 GENERAL FACILITY DESCRIPTION

Plant X is a textile mill located in City X, Country X. The mill is a fully integrated textile operation producing poly/cotton bed sheets for the local market. Three standard widths of sheets are produced 1.8 meters (m); 1.5 m and 2.0 m. The average fabric density is 0.125 kilograms (kg)/m. The average monthly production is 660,000 m/month (83 metric tons (MT)/month ) or 996 MT/year. The facility produces four products in the following proportions: bleached fabric, dyed fabric, printed on white fabric and printed on dyed fabric at 5%, 13%, 36% and 46%, respectively.

The facility employs 450 people: 400 as facility operators and 50 as administrative staff. The facility operates three 8-hour shifts per day, 5.5 days per week. Operations are split into two areas: dry processing for fiber and fabric production and wet processes for preparation, dyeing, printing and finishing. This analysis focuses solely on the wet operations for preparation, dyeing, printing and finishing.

3.2 PROCESS OPERATIONS

Process operations reviewed as part of this study include: singeing, quenching, desiring, bleaching, washing, dyeing, heat setting, printing, curing and finishing. A description of each operation is provided. Table 2 defines the process sequences for each of the four Plant X products.
**Table 2**

**Plant X Production Sequence by Product Type**

<table>
<thead>
<tr>
<th>Bleach Only</th>
<th>Dye Only</th>
<th>Print (White Background)</th>
<th>Dye and Print</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleach</td>
<td>Bleach</td>
<td>Bleach</td>
<td>Bleach</td>
</tr>
<tr>
<td>Wash</td>
<td>Wash</td>
<td>Wash</td>
<td>Wash</td>
</tr>
<tr>
<td>Heat Set</td>
<td>Heat Set</td>
<td>Heat Set</td>
<td>Heat Set</td>
</tr>
<tr>
<td>Finish</td>
<td>Dye</td>
<td>Print</td>
<td>Dye</td>
</tr>
<tr>
<td></td>
<td>Wash</td>
<td>Cure</td>
<td>Wash</td>
</tr>
<tr>
<td></td>
<td>Heat Set</td>
<td>Finish</td>
<td>Heat Set</td>
</tr>
<tr>
<td></td>
<td>Finish</td>
<td></td>
<td>Print</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Finish</td>
</tr>
</tbody>
</table>

**Singe/Quench/Desire** - All poly/cotton fabric is sized with carboxymethyl cellulose (CMC) prior to weaving. Once woven, the fabric undergoes a singeing operation to remove short fibers and a desiring operation to remove the CMC size from fabric. This operation is a continuous process that feeds fabric through the system at a rate of approximately 120 meters/minute. The operations consists of the following four steps: Sized fabric is

1) singed with Liquid Petroleum Gas (LPG),

2) quenched in a cold water bath (overflow water rate was not available),

3) desized in a detergent bath at 120EC. The desire bath has five chambers. The bath volume was not provided. Detergent is mixed into the first fill of water in the bath. Water is fed continuously to the bath during the process, quickly exhausting the detergent within the first several minutes. The bath is heated directly with steam.

4) dewatered by rollers which squeeze excess water from fabric.

All process wastewater is discharged directly to the sewer. The total processing time for this segment is approximately 1.5 hours.
**Bleaching** - After the desiring operation, fabric is fed to the bleaching operation at a rate of 25 meters/minute. The bleaching operation consists of the following three steps. The first two are continuous feed:

1) A mixture of H\textsubscript{2}O\textsubscript{2}, NaOH, detergent and a peroxide stabilizer is fed to a single 800 liter bath for the first stage of the bleaching process. This bath is made-up at different compositions depending on the width of the fabric. Table 3 shows the chemical compositions. The first 2000 meters of fabric are fed through the first bleach fill of 300 liters. The bath is emptied and refilled to 500 liters for the remaining 4000 meters of fabric. Baths are discharged directly to sewer. pH and oxidation reduction potential (ORP) are not routinely measured.

2) After the bleach bath, the fabric is fed through a vaporizer chamber heated by direct steam at 100 to 120 \textdegree C.

3) The final bleaching stage requires the fabric beam to be placed in a reaction chamber where it is rotated for approximately 2 hours. The chamber is heated continuously with direct steam to maintain an operating temperature of 110-120 \textdegree C. Steam condensate drains from the chamber to the sewer. The discharge rate of condensate is unknown.

**Table 3**

<table>
<thead>
<tr>
<th></th>
<th>1.5 m</th>
<th>1.8 m</th>
<th>2.0 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>H\textsubscript{2}O\textsubscript{2}</td>
<td>18 kg/800 l</td>
<td>22 kg/800 l</td>
<td>30 kg/800 l</td>
</tr>
<tr>
<td>NaOH</td>
<td>17 kg/800 l</td>
<td>22.5 kg/800 l</td>
<td>22.5 kg/800 l</td>
</tr>
<tr>
<td>Stabilizer</td>
<td>5.5 kg/800 l</td>
<td>6.5 kg/800 l</td>
<td>9 kg/800 l</td>
</tr>
<tr>
<td>Humectant</td>
<td>1.4 kg/800 l</td>
<td>1.7 kg/800 l</td>
<td>2.3 kg/800 l</td>
</tr>
</tbody>
</table>

**Washing** - Fabric is washed after the bleaching process and after the dyeing process. Water remaining in the baths after bleaching is reused for another bleaching rinse or for a dye rinse. All water is discharged after a dye wash and the unit completely refilled for the next batch.
The washing line is a continuous system which operates at a fabric feedrate of 45-50 m/min. The wash line has seven wash boxes and has two separate stages of countercurrent flow. As shown in Figure 1, Boxes 1, 2 and 3 are heated by direct steam to 90°C, flow runs countercurrently from Box 3 to Box 1 and is discharged to the sewer from Box 1 at a rate of 1.64 liters/second. Boxes 4 and 5 are stagnant detergent baths heated by steam to 90°C. Boxes 6 and 7 are cold rinse baths that are fed countercurrently from Box 7 to 6 at a flowrate of 2.26 liters/second and then discharged directly to the sewer. The entire operating time to feed a batch of fabric through the wash process is approximately 2.5 hours (including loading and draining). The equivalent operating time for the wash system is estimated to be 20 hours/day.

**Heat Setting** - To avoid shrinkage, all washed fabric is processed through a thermosetting process. First, fabric is fed through a heated roller system to remove approximately 10% of the moisture content and to evenly spread the water through the fabric. The fabric is then fed through a rama (tinterframe) for drying.

**Dyeing** - The dyeing process has a feedrate of 36 meters/minute and an effective batch operating time of 3 hours. Dyeing occurs in a jig (pad-dye) type machine where the fabric is fed through a shallow dye bath/trough. The facility dyes primarily light colors. Only the cotton is dyed and 100% reactive dyes are used. Information on specific dye bath compositions and dye chemistries was not provided. Process operators indicated that a sodium carbonate solution is mixed in with the dye and humectant. Dye baths are discharged to the sewer at the end of a batch run. After dyeing the wound fabric beams are spun for approximately 2.5 hours to allow the dye to further react. The fabric is then fed through the washing line again under the same process conditions previously described for washing after bleaching.

**Printing** - The facility has two rotary screen printing lines; only one was in operation during the visit. Each line consists of 8 printing cylinders. Fabric is fed through the print system and into a dryer to set the ink. The dryer operates at a temperature of 150°C. The estimated residence time of fabric in the dryer is 2 minutes. The system feedrate is 30-45 meters/minute. A single printing batch takes and estimated 3 hours to run through the printing process. The equivalent operating time for the printing operation is 16 hours/day.

Each print cylinder is connected to and draws ink from a dedicated colored-ink bin. The fabric feed belt is continuously rinsed with ambient temperature water to remove ink. The incoming Rinse water flowrate is 2.62 l/s. A constant stream is diverted from the rinse outflow stream and recycled to the rinse process.
Printing inks are fed from plastic barrels to each roller. The ink batches are made-up in what appears to be either 200-400 kg batches. There is some attempt to reuse leftover inks to make-up darker colors; however, it appears that several of the barrels are simply washed out at the end of a printing run and discharged to sewer. Ink nozzles are washed out after each run at a washing station equipped with brushes and discharged directly to sewer.

Printing screen cylinders are photoengraved to produce the printed patterns. Cylinders are made of nickel and cost $135 US. each. Cylinders with standard Plant X patterns are stored for future use. Old and unused cylinders are crushed and sold for scrap. The facility is interested in identifying alternative lacquer materials that can be removed with a solvent in order to reuse the cylinders. The previous solvent used to remove lacquer was too toxic and the operation was stopped over a year ago.

**Curing** - After printing all fabric is fed through a curing operation. The feed rate through this process is approximately 20-25 meters/minute; one batch requires 4 hours of processing. The estimated residence time for fabric in the curing chamber is 4 minutes. A single curing chamber, heated indirectly by a thermal-oil heat exchange system to 150°C, is used for all printed batches.

**Finishing** - Finishing consists of a softening process and pressing or calendering. The softening process occurs in a Foulard machine where a formaldehyde-based resin is applied to the fabric. The fabric is then continuously fed through a drying rama (tinterframe). The feedrate of this system is 18 meters/minute, one batch is approximately 5.5 hours. After applying wet finish, fabric is processed through a calendering operation which presses the fabric before folding and packaging. Calendering requires approximately 4 hours.

**Chemical Use/Dye and Pigment Preparation** - The pigments and chemicals are stored in one room located off of the main dyeing operation area. Pigments and dyes are mixed in the same area. Materials are weighed and dispensed manually by operators. No automated systems are in place. Washing of mixing bins also occurs in the same area. All washwater from this room is discharged to the sewer.

**Water and Energy Use**

All process water is pumped from three wells. The dyeing/finishing operation is estimated to use approximately 8.5 l/s or 734 m³/day (17,480 m³/month). Approximately, 0.5 l/s is used as boiler feed, 7 l/s feeds the process operations and 1 l/s feeds the HVAC system. Incoming water has been measured at a hardness of 120-150. Water is pumped to a 104 m³ cistern and then pumped, untreated directly to boilers and processes.
The dyeing/finishing operations use a variety of energy sources: Diesel oil #6 (Bunker) is used to heat the three boilers that supply direct and indirect steam to the processes; Diesel oil #2 is used to fire two thermal-oil heaters which supply a heat exchange medium to heat one rama (tinterframe) and the curing chamber; LPG supplies heat to one drying rama and to the singeing operation; and electricity is supplied to run the motors, compressors, fans, pumps, and lighting. Table 4 shows annual fuel use rates and Table 5 shows the electricity demand by process.
Table 4
Fuel Loading for Dyeing/Finishing Operations

<table>
<thead>
<tr>
<th>FUEL</th>
<th>SUPPLIED TO</th>
<th>VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunker</td>
<td>Boilers</td>
<td>28,000 gal/mos</td>
</tr>
<tr>
<td>Diesel</td>
<td>Thermal-oil Heaters</td>
<td>9,000 gal/mos</td>
</tr>
<tr>
<td></td>
<td>Emergency Generators</td>
<td>1,500 gal/mos</td>
</tr>
<tr>
<td>LPG</td>
<td>Rama</td>
<td>11,000 kg/mos</td>
</tr>
<tr>
<td></td>
<td>Singeing</td>
<td>3,000 kg/mos</td>
</tr>
</tbody>
</table>

Table 5
Electricity Loading for Dyeing/Finishing Operations

<table>
<thead>
<tr>
<th>Process</th>
<th>KW</th>
<th>Daily Equiv. Operating Time</th>
<th>Monthly Load (KWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rama #1</td>
<td>70</td>
<td>16</td>
<td>24,640</td>
</tr>
<tr>
<td>Rama #2</td>
<td>85</td>
<td>16</td>
<td>29,920</td>
</tr>
<tr>
<td>Rama #3</td>
<td>130</td>
<td>16</td>
<td>45,760</td>
</tr>
<tr>
<td>Bleach</td>
<td>12</td>
<td>16</td>
<td>5,280</td>
</tr>
<tr>
<td>Washing</td>
<td>20</td>
<td>20</td>
<td>8,800</td>
</tr>
<tr>
<td>Printing</td>
<td>60</td>
<td>16</td>
<td>21,120</td>
</tr>
<tr>
<td>Calendering</td>
<td>50</td>
<td>16</td>
<td>17,600</td>
</tr>
<tr>
<td>Spinners</td>
<td>15</td>
<td>16</td>
<td>5,280</td>
</tr>
<tr>
<td>Total</td>
<td>442</td>
<td></td>
<td>158,400</td>
</tr>
</tbody>
</table>

Environmental Effluents

All process wastewater is discharged to the sewer untreated. BOD and COD loadings have been measured previously by an independent company; however, the facility does not consider the results of the previous study reliable.
All heated operations are vented directly to the atmosphere. Standard measurements of stack gases are not routinely taken. Boiler stack gases were recently vented to scrubbers. Water and calcium carbonate are mixed to reduce the acidity and remove hydrocarbons, particulates, etc. from the flue gas. Scrubber water flows at 15 m$^3$/day and is discharged to a 2 m$^3$ settling basin and the overflow goes directly to sewer.
CHAPTER 4
ANALYSIS AND RECOMMENDATIONS

4.1 GENERAL APPROACH

In general, Plant X is a well run operation. The facility is quite clean, production appears to run smoothly, and there are no major environmental or product quality problems imposed by existing operations. Several potential improvements to the dyeing/finishing processes are considered in the following discussion. The recommendations appear in order of priority of importance. Instituting a lower priority recommendation before a higher one may minimize the full potential benefits.

The limited available data on chemical use, accurate water flow rates and energy use and system loading restricts an adequate analysis of operations. For example, without specific operating details for each heating process, it is difficult to adequately assess energy reduction potential. Similarly, without adequate flowrate measurements of process water, water reduction savings are difficult to assess. The water use rates supplied by the facility operators for process operations were quite different than those estimated by assessing the individual process operations. The analysis and recommendations are based on our observations and general engineering assumptions for similar operations.

In cases where data was available but uncertain, assumptions were made to attempt some cost saving potential. Cost savings were qualified to the best extent possible, but are considered to be very rough estimates. These assumptions are discussed in each recommendation. In many cases, data for analysis was unavailable, so each recommendation is discussed in terms of its potential benefit only, followed by details on how to determine if the recommendation could be effective. The majority of the recommendations require further investigation by the Plant X process operators to qualify the assumptions, gather better data and evaluate the proposed recommendations.
4.2 **ANALYSIS AND RECOMMENDATIONS**

4.2.1. **Develop Standard Operating and Audit Procedures.** Plant X has no formal written procedures documenting the majority of process operations. Each shift manager appears to have a different understanding of the operating parameters of the various processes. Actual rates of water and energy use could not be compared to theoretical use because the facility does not measure these parameters to any reasonable degree. In order to effectively measure improvements to productivity and associated cost savings, standard operating procedures and a system to ensure these procedures are adhered to (e.g., routine audits) must be implemented. Once the procedures are documented and consistently checked for compliance, it is then appropriate to modify the system to evaluate improvements in productivity as discussed in the following recommendations.

The following information should be characterized and documented in a computerized database. The operating parameters should be routinely checked and recorded to enable Plant X management to assess consistency and productivity.

<table>
<thead>
<tr>
<th>Chemical Usage (Dyes, Pigments, Auxiliaries, etc.)</th>
<th>Monthly Use kg/m fabric Chemical Loadings to each Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Usage</td>
<td>Steam and Energy Loadings to all Processes</td>
</tr>
<tr>
<td>Water Usage</td>
<td>Gross Inflow and Outflow to/from Facility</td>
</tr>
<tr>
<td></td>
<td>Flowrates to all Wet Processes</td>
</tr>
</tbody>
</table>

**Calculations and Assumptions:** A computer station and software to accomplish this monitoring and tracking should be located in the dyehouse. The cost of such a system should be approximately US$2,000. The internal labor effort to establish the program would be high at first but would save time over the long term.

**Obstacles to Implementation:** Training would be required. Record-keeping would require time, however operators should be able to collect data as part of ongoing responsibilities.

**Schedule of Implementation:** Investigate options for database management and select a computer system within three months. Begin building a database, and, along with optimizing other processes, have the control system in place within nine months.

**Follow-up Measurement:** EP3 should assist in technology evaluation and selection. EP3 assistance also may be beneficial in setting up initial database structure and standard operating procedures.
4.2.2. **Reuse rinse water from Boxes 6 and 7.** Relatively clean rinse water from the latter stages of the washing operation (Boxes 6 and 7) should be conveyed to the early stages of the wash unit (Box 3) for continued use in washing, instead of directly discharging to the sewer. (Please refer to Figure 1.)

**Calculations and Assumptions:** Presently, approximately 163 m$^3$/day of wash water is discharged after limited contact with goods in the final stages of washing. This water is relatively clean and can be routed to early stages of the wash operation by installing new piping for approximately US$2,000. Savings in water pumping costs of US$2,400 per year will be realized by this process improvement (pumping cost estimates are based on information provided by the facility). In addition, this minor modification will reduce wastewater flow by 20 percent; the result of the flow reduction will be to lower future wastewater treatment capital costs by US$100,000 and annual operating costs by US$10,000.

**Obstacles to Implementation:** This improvement opportunity will be relatively simple to implement. The cost for implementation will be minimal. Perhaps the greatest obstacle will be the change to current operations. However, with minimal effort from production staff, the improvement can be implemented.

**Schedule of Implementation:** Detailed study and design of the modification can be initiated immediately. During detailed study, the effect of the modification on the washing process can be confirmed. These arrangements can be completed and the new piping installed in less than one month.

**Follow-up Measurement:** EP3 should assist in planning the modification, as necessary. Confirmation of the improvement can be accomplished by visual observation of the dyeing operation.
4.2.3. Reuse Final Overflow From Bleach-Washing In Desiring. Overflow from Box 1 during washing of bleached goods should be collected daily and reused in the desiring operation.

Calculations and Assumptions: The final overflow of wash water from Box 1 to the sewer will contain minimal contamination during washing of bleached goods. The same detergents used in the washing operation are utilized in desiring and bleaching. The presence of caustic (NaOH) from recycled bleach-batch wash water will facilitate better cleaning of the fabric by providing some scouring in the desiring operation.

A holding vessel for the recycled water will be required to temporarily hold wash discharge when processes are not run concurrently. A vessel could be installed or constructed beneath the existing wash range, and the recycled water could be pumped to the desiring operation as needed. Another alternative would be to install another holding tank near the desiring operation; recycled water could be pumped to this tank immediately and fed by gravity into the desiring operation. The capital cost for this modification should be less than US$20,000.

The total overflow from Box 1 during washing of bleached goods should be approximately 100 m$^3$/day (based on an estimate of 5 bleach batches per day). Since the flow required in desiring, based on standard practice (which is less than current operational estimates), should be 100 m$^3$/day, the overflow wash water available should satisfy the needs for desiring. Accordingly, recycle of bleach wash water for desiring would result in a water savings of 100 m$^3$/day.

Any savings in well water pumping costs would be offset by the new cost of pumping the recycled water. Some savings in detergent could be realized because less new detergent would be required in desiring. Also, including caustic in the desire operation could reduce detergent requirements in bleaching by providing a cleaner fabric from desiring. The chemical cost savings likely would be less than US$2,000. Energy savings would be realized because the desiring operation requires water at 120°C and the wash water from the rinsing operation leaves the process at 90°C. Therefore, the desiring operation would reduce its current steam load requirements because water is incoming at a much higher temperature. Assuming that the wash water temperature cools to 70°C during intermittent storage and the water loading to the desire operation is reduced from the estimated 150 m$^3$ day to 100 m$^3$/day. Saved energy is calculated based eliminating the heat steam requirements to heat 50 m$^3$/day of 15°C water to 120°C, 5250 Thermies (1 Thermie = 10$^6$ calories), and the heat required to raise the 100 m$^3$/day from 15°C to 70°C, 5500 Thermies. We assume a steam delivery efficiency of 55% (based on pre-assessment information/calculation), a boiler efficiency of 75%, a heat of combustion of 154,000
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Btu/gallon and a cost of $0.25/gallon for Bunker fuel. The total Bunker fuel savings per/month is estimated to be 12,500 gallons which is equivalent to a cost savings of approximately $3,100/month or $37,000/year. (Note, this value indicates that the desiring operation is using approximately 40% of the steam loading to the facility. This number appears to be very high and is not considered accurate. The value was calculated based on the assumed water volume to the desiring operation. The facility needs to check the desired water volume and heating load to better qualify this value.)

The most noticeable savings would be in future wastewater treatment capital costs. Recycling wash water to desiring would result in a reduction in total wastewater flow of 15 percent. This water use reduction would translate to capital and annual operating cost savings of US$75,000 and 7,500, respectively, for a future wastewater treatment facility. The cost of the wastewater treatment system is based on a US estimate of US$2.50 to 3.00/gallon/day, and the yearly wastewater treatment cost is assumed to be 10% of the system=$ capital cost. These figures should be evaluated and reviewed with local suppliers and not taken as absolute costs.

Obstacles to Implementation: This improvement opportunity should be investigated carefully. The feasibility of the operation will depend upon timing of process operations, and the actual cost of installing a water storage and pumping unit. This modification would require a significant commitment from production staff, since it would add an extra step to the desiring operation.

Schedule of Implementation: Flow rates and timing of process operations should be studied carefully to confirm the feasibility of this improvement. These evaluations could be conducted in three months. Design of modifications could be completed in three months, and new equipment could be in place in an additional three months. In summary, these changes could be made within nine months, probably more rapidly, if desired.

Follow-up Measurement: EP3 staff should participate in further evaluation of the effectiveness of this modification. A formal engineering study, design, and installation schedule should be developed and followed.
4.2.4. Optimize Desire Operation. Opportunities exist to reduce water use in the desire operation by evaluation of several process changes:

- Installation of high velocity water nozzles will scour the fabric with less overall water use.
- Operation at a higher temperature (typically 180°C) will allow less water use by providing better size removal.
- Application of caustic soda (NaOH) in desiring may improve cleaning and reduce chemical requirements in the bleaching operation.
- Utilizing the final wash water overflow from bleach-washing in desiring could provide significant overall reduction in water use, as discussed in Recommendation 3 above.

Calculations and Assumptions: Each of these improvement opportunities should be investigated further. Estimating costs and performance for these alternatives would not be prudent utilizing the available information. In general, a relatively small capital investment in equipment would be necessary to provide high velocity scour washing. Operation at a higher temperature should be possible but would increase energy costs. Application of caustic soda in the desiring operation would have an insignificant cost and may save chemical costs in other processes.

Although reliable data on the flow rate from the desiring operation is not available, estimates have placed the flow at approximately 150 m$^3$/day. A reduction in desiring water use of 30 percent should be achievable. This reduction would equate to an overall water use reduction of 7 percent. The pumping costs saved would be minimal but could exceed US$800 per year. Savings in future wastewater treatment costs would be US$35,000 for capital and US$3,500 for annual operations.

Obstacles to Implementation: Implementing these modifications would change current operations and may appear to restrict manufacturing flexibility. Backup systems could be established to maintain flexibility. The primary obstacle to direct implementation of these improvements is the need to further investigate these alternatives.

Schedule of Implementation: Items 1 through 3 can be investigated concurrent with planning for reuse and recycle of wash water and can be implemented as soon as their effectiveness is confirmed. With reasonable allowances for study, this recommendation could be implemented within three months.
**Follow-up Measurement:** Although production staff will need to be involved in testing these alternatives, EP3 staff should provide support and help establish a schedule and study plan for the investigations.
4.2.5. Optimize Bleaching Operation. Opportunities may exist for better use of process chemicals and water in bleaching operations.

Calculations and Assumptions: The pH of the bleach bath should be monitored to establish conditions in the optimum range from 10.5-11.0 standard units. A database of oxidation-reduction potential (ORP) also could be established to allow effective bleach bath formation based on ORP and pH. A cost would be incurred to purchase monitoring equipment and train personnel in its use. These costs would be less than US$2,000.

Reuse of the bleach solution for several process runs may be possible simply by reconstituting the bath with hydrogen peroxide. The savings in water use would be minimal, but this practice would minimize the discharge of caustic to the sewer. Aside from the environmental benefit of less caustic discharge, a cost savings in caustic could be realized. The total annual expenditure for caustic in bleaching is approximately US$7,000. If each bleach bath can be reused one time, a savings of US$3,500 per year would occur.

Obstacles to Implementation: Again, these modifications may appear to reduce manufacturing flexibility and may be resisted. They also will require some study and training.

Schedule of Implementation: The process should be studied and implemented immediately. A reasonable allowance for equipment purchase and training would be two months. Process testing for development of a database and optimization of the process could occur for two months. The overall implementation should require four months.

Follow-up Measurement: EP3 staff should assist with recommendations for monitoring equipment and help develop a study plan and determine feasibility.
4.2.6. **Optimize Washing Operation.** Along with reusing latter rinses and final overflow, as described in Recommendations 2 and 3, respectively, additional reductions in wash water use should be possible.

**Calculations and Assumptions:** Controlling leaks in the unit, carefully considering the need to waste full wash boxes to the sewer, and, possibly, washing with high velocity jet nozzles can provide a wash water use reduction of 10 percent. These results translate to an overall reduction in water use of 5 percent. Well water pumping costs can be reduced by US$500 per year, and the capital and annual operating costs of future wastewater treatment would be reduced by as much as US$25,000 and 2,500, respectively.

During EP3 on-site investigations, a leak of 34 m$^3$/day was noted. Assuming a boiler efficiency of 75% and a steam delivery efficiency of 55%, the equivalent fuel savings which would result from plugging this leak are:

Heat loss from leak $= (34 \times 10^6) \times 75°C \times 2.55 \times 10^9$ cal/day $= 56,100$ Thermies/month

Total heat loss at the boiler $= 56,100 \times (1/0.75) \times (1/0.55) = 136,000$ Thermies/month

Potential fuel savings $= 136,000 \times (3,968$ Btu/Thermie) $\times (1$ gallon of fuel/154,000 Btu)$

$= 3,500$ gallons/month $= US$ 875/month

$= US$ 10,500/year

**Obstacles to Implementation:** Minimal obstacles to implementation exist for this improvement opportunity.

**Schedule of Implementation:** Control all unnecessary leaks and overflows immediately. Evaluate the effectiveness of high-velocity wash nozzles over the next three months.

**Follow-up Measurement:** EP3 and the company should monitor progress as part of the overall flow monitoring effort.
4.2.7. Optimize Printing Operations. Two primary opportunities to improving printing operation are improving the wasted heat from the curing operation and reducing waste from pigment application.

Calculations and Assumptions: The curing chamber did not appear to be insulated and is responsible for using 6,300 gal/mos of diesel to run the Dow-therm type heating unit. With effective insulation, the heating load could be reduced up to 15% which would result in an estimated fuel savings of up to 1,200 gallons of diesel (assuming a 75% heat transfer efficiency) which would save approximately $1,575/month or $18,900/year in diesel costs. Plant X should also evaluate the effectiveness of the drying and curing operations to determine if the residence time of the fabric in each process can be improved upon. The facility should evaluate the potential for decreasing the residence times through the drying and curing processes, and consider the effectiveness of using a single continuous system for drying and curing. Either option could result in decreasing the equivalent printing operation process time. Some textile facilities use a single chamber for both drying and curing, but this type of operation requires effective process control to ensure that moisture is removed consistently across the fabric so that curing can occur.

Note: A review of textile industry energy consumption was conducted by the US Department of Energy in 1985. The study indicated an average curing heat load for woven fabrics at 416 kcal/kg fabric. Based on the Diesel loading data given by the facility to the consultants, it is estimated that the Plant X operation is using 5,065 kcal/kg.

Plant X should evaluate the quantity and cost of pigment wasted per batch of fabric and develop a standard system for reusing pigments from daily batches and evaluate pigment recovery potential. Pigments should be reused in darker shades where appropriate. A computer-based record of formulas would assist in matching shades and allow the appropriate amount of pigment to be prepared without excess. Also, pigment is most likely recoverable from printer belt washwater. Membrane technologies are used to recover pigments. Capital cost of these technologies for an average textile printing wastestream run approximately $3.00-$4.00/gallon of water/day.

Obstacles to Implementation: Even if the drying/curing could be effectively combined into one step as described above, it would increase the time for a printing batch on the printing line from 3 hours to 5 hours which impacts production. Typically, 5 print batches are completed in one day, requiring an equivalent 16 hours operating time. If the speed is reduced by half, the printing operation would need to be run for an equivalent 25 hours, which will not be feasible in one day. This recommendation could be implemented when the other printing line is up and running.
Schedule for Implementation: The facility should attempt to run trial print batches through the printing operation at reduced speed to determine if ink is adequately cured. This could be accomplished within the next three months. Once the second printing line is running, this option should be implemented.

Follow-up: EP3 should check back with Plant X on the schedule for reinstalling the second print line and the results from testing a single heat/cure step.
**4.2.8. Install vacuum slot de-watering device** for fabrics entering dryer after washing and after finishing. Cotton/polyester fabric likely holds 0.7 kilograms of water/kilogram of fabric after squeeze rollers. A vacuum slot will reduce these figures to no higher than 0.5 kg/kg, another ~30% reduction in water loading to the dryer. The device could be applied to fabric after washing, dyeing and finishing operations.

**Calculations and Assumptions:** Currently, the dryer must heat and evaporate 57,750 kg $\text{H}_2\text{O}$/month (based on fabric loading of 660,000 meters/month. Assuming the dryer operates at 120°C, water on the fabric needs to be raised from 15°C to 90°C, and the heat of vaporization of $\text{H}_2\text{O}$ is 500 kcal/kg the total thermal loading required 33,206 Thermies/month. If a vacuum slot system is installed and reduces the water loading on the incoming fabric to the dryer to 41,250 kg, the net monthly energy savings is 9,500 Thermies/month.

The fuel loading to the tinter frame located next to the washing line is approximately 2,260 gal/mos diesel fuel #2. If a 20% heat savings can be provided by installing the vacuum slot system, a total of 5,432 gal/year can be saved. The cost savings associated with this operation are approximately $6,790/year.

If fabric after the wet finish operation was also run through the vacuum slot dewatering system, it would double the thermal savings calculated for the dryer. The tinter frame used to dry fabric after the application of the wet finish is heated by steam. If we assume that the steam delivery efficiency to the tinter frame is 40%, the 19,000 Thermies/mos total savings translate into a 1,220 gal/mos bunker fuel savings or a cost savings of $3,700/year.

The total savings from using a vacuum slot dewatering system for drying wet fabric is estimated to be $10,500/year. The cost of a single vacuum slot machine capable of handling the average weight of Plant X fabric is approximately $35,000 to $40,000. If the device was capable of handling daily batches after washing and finishing, the device would pay off in less than 3.5 years.

**Obstacles to Implementation:** The greatest obstacle to implementation is the cost of this equipment. Although the payback may appear to slow to justify, Plant X plans to increase the operation in the coming years which will inevitably increase energy costs. Taking future expansion into consideration, the payback period may decrease.

**Schedule for Implementation:** The facility should attempt to identify local suppliers that provide vacuum system equipment and obtain a local price for this type of equipment. Future capacity increases and future heating requirements should be carefully considered and factored into determining the economic benefit of this option.
**Follow-up:** The facility should follow-up with local suppliers of vacuum equipment. EP3 staff could assist in evaluating technical and economic feasibility.

**4.2.9. Reduce Electrical Consumption by Replacing Old Motors.** The majority of process operations use motors older than 20-30 years. Motor efficiencies have been greatly improved and reasonably priced motors are available. Plant X should consider replacing the majority of large motors over time to minimize electricity consumption.

**Calculations and Assumptions:** Based on the facility estimated electrical loadings for each process operation, an assumption was made relative to the percentage of the load supplied to motors. If old motors were replaced with efficient motors, a minimum of 15-20 energy savings could be achieved. An approximate electrical savings estimate is 15,350 kWh/mos which is the equivalent savings of $14,700/year.

<table>
<thead>
<tr>
<th>Process</th>
<th>KWh</th>
<th>% draw by motors</th>
<th>Equiv. Hours</th>
<th>KWh Saved/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleach</td>
<td>12</td>
<td>70</td>
<td>16</td>
<td>20</td>
</tr>
<tr>
<td>Wash</td>
<td>20</td>
<td>100</td>
<td>16</td>
<td>48</td>
</tr>
<tr>
<td>Print</td>
<td>60</td>
<td>30</td>
<td>16</td>
<td>44</td>
</tr>
<tr>
<td>Calender</td>
<td>50</td>
<td>50</td>
<td>20</td>
<td>75</td>
</tr>
<tr>
<td>Tinter frame #1</td>
<td>70</td>
<td>50</td>
<td>20</td>
<td>105</td>
</tr>
<tr>
<td>Tinter frame #2</td>
<td>85</td>
<td>50</td>
<td>16</td>
<td>102</td>
</tr>
<tr>
<td>Tinter frame #3</td>
<td>130</td>
<td>50</td>
<td>16</td>
<td>156</td>
</tr>
<tr>
<td>Rollers</td>
<td>15</td>
<td>100</td>
<td>16</td>
<td>64</td>
</tr>
<tr>
<td>Total/Day</td>
<td></td>
<td></td>
<td></td>
<td>614</td>
</tr>
<tr>
<td>Total/Year</td>
<td></td>
<td></td>
<td></td>
<td>184,000</td>
</tr>
<tr>
<td>Total $ Saved/Yr</td>
<td></td>
<td></td>
<td></td>
<td>$14,700</td>
</tr>
</tbody>
</table>
4.2.10. Improve Mixing of Dye and Sodium Carbonate Solutions. The use of sodium carbonate in conjunction with a reactive dye in a cold bath helps to drive the reaction of dye with the fiber and is commonly used in pad-dye bath operations. However, common industry practice employs good mixing of the materials to ensure proper and even dyeing. It was observed that Plant X mixes the two solutions in pipe before feeding to the dye trough which may not facilitate sufficient mixing. Spotting was observed on several batches of dyed fabric and is probably due to insufficient mixing of the dye solutions and sodium carbonate solutions in addition to the hardness of process water. Facility operators claim that rework is not required even though the dye process may leave spots because practically 50% of the dyed fabric is printed and will conceal any dyeing imperfections. However, if Plant X expands its market into higher quality fabrics, this operation will need to be improved.

A simple in-line mixing trap installed just after the point where the two solutions are mixed together would provide adequate mixing. The implementation of this recommendation should not cost more than a $200.

Obstacles to Implementation: There are no obstacles to implementation of this recommendation. However, Plant X has no pressing reason to improve the dye operation at this time.

Schedule for Implementation: This option could be implemented immediately.

Follow-up: The facility should track and document dye batches where spotting occurs to determine dye efficiency rates. If a batch of fabric ever requires reworking, the minimal investment in a mixing system would instantly pay for itself.
4.2.11. **Maximize Dye Exhaustion.** Ensure that the dye process maximizes chemical use.

**Calculations and Assumptions:** Exhaustion of the reactive dyes should be 90 percent. Exhaustion is the percent of the total dye in the process that is retained on the fabric after dyeing. Practically, it can be calculated by measuring the dye concentration in the dyebath before and after dyeing. Exhaust dyeing may be difficult to control in the present dyeing process and should be investigated.

**Obstacles to Implementation:** No obstacles exist, other than increased monitoring requirements.

**Schedule of Implementation:** Monitoring of exhaustion can begin immediately. Process adjustments can be made immediately, as appropriate.

**Follow-up Measurement:** EP3 should assist in establishing the monitoring program.
4.2.12. **Apply Finish in Dry Operation.** Application of finish could occur in a dry operation following final fabric drying.

*Calculations and Assumptions:* This modification would provide only marginal economic benefits but should be considered for future environmental reasons. Applying the finish in a wet process bath introduces spent finish to the waste stream. Finishes can have limited degradability in a conventional biological wastewater treatment system and can be toxic to aquatic organisms. Capital costs for equipment could be preclusive.

*Obstacles to Implementation:* No immediate economic return on investment can be identified.

*Schedule of Implementation:* The possibility and desirability of applying finish in this manner should be investigated over the next 12 to 18 months in anticipation of future environmental requirements.

*Follow-up Measurement:* EP3 should assist in identifying equipment vendors for this machinery so the company can evaluate the process.
4.2.13. **Manually Clean Printing Equipment.** Discharge and waste of pigments can be minimized by manually cleaning printing equipment prior to final cleaning by a scouring wash.

*Calculations and Assumptions:* Tubs, dippers, cylinders, and nozzles can be wiped clean of pigment prior to water cleaning. The pigments can be returned to supply containers for reuse, as appropriate. Elimination of unnecessary pigment in the waste stream will significantly improve the visual quality of the wastewater, since pigments are persistent in discharges. Water use and chemical oxygen demand reductions would be minimal.

*Obstacles to Implementation:* Marginal economic benefit would be realized, and implementation would require discipline and control.

*Schedule of Implementation:* Implement immediately. Develop long-term management plan over the next three months to ensure continued compliance.

*Follow-up Measurement:* EP3 should assist in management plan development.
4.2.14. **Evaluate Water Softener for Boiler and Process Water.** Reducing the hardness of the process water (softening) could reduce the amount of detergents required in the processes and minimize fabric spotting. It will also increase boiler efficiency and reduce fuel use and costs.

*Calculations and Assumptions:* Softening process water would reduce the amount of detergent required in cleaning fabric. The total annual expenditure for detergent is approximately US$18,000. Some fraction (probably less than 50 percent) of these costs could be recovered by softening the process water.

If market focus changes and fabric spotting becomes an important problem, installation of a softening process could provide a significant return on equipment investment. The cost of a system will be US$50,000-100,000 and should be evaluated with respect to future market focus for products from the company. This process may allow the company to access new markets.

*Obstacles to Implementation:* Minimal immediate economic justification can be made.

*Schedule of Implementation:* Investigate system costs and feasibility of installation over the next 12 months.

*Follow-up Measurement:* EP3 should provide support with vendor information and target to seriously consider the operation within 12 months.
4.2.15. **Institute a Water Monitoring Program.** In concert with the process database, data should be collected from each unit operation. This information will be essential to tracking the progress of the pollution prevention program. More important, the data will provide the basis for future decision-making in manufacturing and wastewater treatment.

The following data should be collected at a minimum:

- Flow Rate (Already addressed in Recommendation #1)
- Temperature
- pH
- Chemical Oxygen Demand (COD)
- Total Dissolved Solids (TDS)
- Heavy Metals (Cadmium, Chromium, Cobalt, Copper, Lead, Mercury, Nickel).

The data listed above should be collected at each of the following unit processes with the frequency as shown:

<table>
<thead>
<tr>
<th>Process</th>
<th>Weekly</th>
<th>Monthly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desiring</td>
<td>A,B,C,D</td>
<td>E,F</td>
</tr>
<tr>
<td>Bleaching</td>
<td>A,B,C,D</td>
<td>E,F</td>
</tr>
<tr>
<td>Dyeing</td>
<td>A,B,C,D</td>
<td>E,F</td>
</tr>
<tr>
<td>Bleach-Washing</td>
<td>A,B,C,D</td>
<td>E,F</td>
</tr>
<tr>
<td>Dye-Washing</td>
<td>A,B,C,D</td>
<td>E,F</td>
</tr>
<tr>
<td>Finishing</td>
<td>A,B,D</td>
<td>E,F</td>
</tr>
<tr>
<td>Printing</td>
<td>A,D</td>
<td>E,F</td>
</tr>
<tr>
<td>Photo-engraving</td>
<td>A</td>
<td>D,E,F</td>
</tr>
</tbody>
</table>

Continuous flow measurement by an in-line device should be conducted for desiring, washing, and printing.

**Calculations and Assumptions:** The cost for analyses, as listed above, will be US$1,300 per month. The cost for installation of continuous flow monitoring equipment will be US$2,000. The labor effort required to sample for these parameters will be 10 hours per
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Month. A direct payback cannot be calculated, but these costs must be considered as a portion of the investment for other process improvement recommendations. In addition, the potential savings in chemical costs, water use, energy cost, and future wastewater treatment requirements is significant.

These data will ensure that informed decisions are made about process changes and wastewater treatment and that future investments are made effectively. In other words, these data will allow control or treatment technologies to be applied to the most effective areas in the operation, thereby potentially saving US$100,000’s.

Obstacles to Implementation: A direct cost for analyses and a labor cost for sampling and record-keeping will be incurred. Establishing an initial sampling protocol will be time-consuming, but subsequent monitoring will be much simpler.

Schedule of Implementation: The monitoring program can be implemented immediately and should be conducted for at least three months to establish a reliable data record.

Follow-up Measurement: Data should be reviewed monthly by EP3. Data should be utilized in ongoing process optimization analyses. These data will confirm assumptions utilized in this study and will allow progress to be tracked.
4.2.16. **Evaluate a Computer-Based Color Matching System.** A computer-based color matching system will reduce water and chemical use over the long term and improve process control. The system would allow reuse of existing colorants by photometrically determining the color and developing a formula needed to use the existing colorant for a new shade.

*Calculations and Assumptions:* Typically, computer-based color matching systems, utilizing a spectrophotometer for color measurement, cost US$10,000. If significant potential savings are identified in evaluations of the printing and dyeing processes, a color-matching system may be appropriate.

*Obstacles to Implementation:* No immediate economic return can be quantified.

*Schedule of Implementation:* Investigate appropriate systems over the next 18 months and implement if economic opportunities are present.

*Follow-up Measurement:* EP3 should provide support with vendor information and target to seriously consider the operation within 18 months.
4.2.17. Process Change Considerations for Future Wastewater Treatment System. If wastewater treatment appears to be necessary, the following process modifications should be considered:

- Substitute a biodegradable size material for CMC.
- Recycle CMC for reuse in sizing and elimination from the wastewater.
- Ensure detergents and wetting agents are degradable.
- Consider more carefully applying finish in a dry operation (Recommendation 7).
- Place greater importance on water use reduction.

Calculations and Assumptions: When wastewater treatment becomes necessary, the conventional method will be aerobic biological oxidation/conversion and removal by sedimentation. This treatment could be accomplished in an on-site facility or at a municipal facility, should City X construct one in the future. Supporting processes, such as pH adjustment and screening, probably would be necessary in either case. With the current flow rate of approximately 734 m$^3$/day (0.2 million gallons per day), a capital cost for a new wastewater treatment facility was estimated to be US$0.75 million, particularly since little infrastructure currently exists. Of the total cost, US$0.25 million was considered to be fixed cost, regardless of wastewater flow.

A greater quantity of biodegradable size material would be required in sizing than CMC, but a starch material would be readily treatable in a conventional textile wastewater treatment facility. Recycle of CMC could offer some monetary savings but would involve capital expenditure. Biodegradable chemicals tend to be more expensive, especially compared to nonylphenol surfactants, which are particularly inexpensive, nonbiodegradable, and toxic.

Obstacles to Implementation: Wastewater treatment is not necessary at this time.

Schedule of Implementation: Study should be initiated immediately to prepare the company for future considerations, especially with respect to water use. Evaluate the current environmental regulatory climate every 6 months and act according to expectations about wastewater treatment.

Follow-up Measurement: EP3 can provide information on chemicals and should provide the company with information on the current environmental regulatory climate every quarter.
CHAPTER 5
CRITICAL RATIO ANALYSIS

5.1 CRITICAL WATER USE RATIOS

The dyeing operations are currently using approximately 209 m³ H₂O/metric ton fabric. Good industrial practice water ratios are typically 100 m³ H₂O/metric ton fabric. This assessment provides relatively low-cost and simple options for achieving this good industrial practice water use level.

5.2 CRITICAL ENERGY USE RATIOS

The dyeing operation uses approximately 1.40 x 10⁹ kcal/month of liquid fuel. Electricity consumption is approximately 0.14 x 10⁹ kcal/month. Total monthly fabric production is 83,000 kg. A critical use ration for energy consumption per unit of fabric is calculated to be 18,507 kcal/kg fabric.

Textiles are an energy intensive industry. However, energy use values are difficult to estimate across the industry because technologies and heating sources vary. An estimate of standard energy use for the textile industry developed by the US Department of Energy in 1985 reported an average value of 15,300 kcal/kg for dyeing of woven fabric. The report also estimated a potential savings of up to 45% using state-of-the art technologies bringing the average energy consumption value down to $8,415 kcal/kg. The recommendations provided in this report could help the facility reduce energy consumption by at least 20% through rather simple measures with reasonable returns on capital investments.
CHAPTER 6
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6.1 PROCESS IMPROVEMENTS/WATER USE REDUCTION

While, it is understood that water is a relatively free resource here in City X, without paying for water or its discharge to the sewer, facilities have little incentive for minimizing usage. While it is not clear when the municipality of City X will mandate wastewater treatment from industries, eventual treatment regulations are inevitable. Plant X has an excellent opportunity at this time to begin analyzing its operations and determining optimal water usage rates for all its processes so that when a wastewater treatment system is designed, the appropriate technology and scale can be selected. The bleaching, dyeing and finishing operations use relatively minor volumes of water. Washing and desiring activities present the greatest opportunities for water use reduction of at least 30%. A 50% reduction is considered achievable if all recommendations are implemented. This latter reduction would bring the facility in-line with Best Industrial Practice water use ratios.

6.2 CHEMICAL RECOVERY

Technologies are available and commonly used in the United States textile industry to recover process chemicals for reuse. Chemical recovery is possible for caustic baths, and desire (e.g., CMC). Membrane technologies are typically used for recovery. Because chemicals are relatively inexpensive, recovery systems are not economically justified for the Plant X operations. In the future, as Plant X expands its operation and increases chemical use, a recovery system for size and caustic may become more economically feasible.

The pigment from the printing blanket washing operation could be recovered and reused in darker pigment make-up with recovery techniques such as membrane technology. The payback of these systems is dependent on the loss of pigment in the washwater. Plant X should consider evaluating the use of pigments and potential savings associated with pigment recovery systems in the future.
6.3 **Energy Savings**

There are several opportunities for Plant X to reduce energy consumption through simple operating practice improvements. Additionally, the facility appears to be wasting a lot of energy from the waste heat resulting from various drying operations which is recoverable with reasonably low-tech equipment that requires capital investment. Unfortunately, the facility did not have sufficient data to evaluate all the potential energy savings. It is strongly recommended that the facility dedicate time over the next year to evaluate energy saving potential, beginning with the recommendations provided in this report, and develop a schedule for phasing-out old inefficient equipment and a phasing in new equipment that can recover waste heat and reduce electricity consumption. It is assumed that simple, low-cost energy conservation measures can reduce energy consumption by at least 10-15% through better insulation and improved process control, and heated bath reuse. Greater energy conservation, at 20-35% can be achieved by implementing some of the recommendations that require capital investment.

Plant X should conduct a comprehensive energy audit which should include the following considerations:

- Maximize output per unit duration of electrically driven machines
- Incorporate effective automatic controls
- Use less water intensive processes or those which require low evaporative drying
- Improve thermal insulation on all steam lines and heating equipment
- Increase energy awareness and process energy monitoring
- Maximize hot water recovery
- Prevent fabric over drying by using humidity sensors
- Employ micro-processor-based moisture controls on dryers and curing ovens
- Recover heat from drying stacks
- Use efficient HVAC units
- Recover boiler condensate
- Maintain steam traps
- Recover boiler blow-down heat.

6.4 **Wastewater Treatment System**

Plant X is currently not required to treat its water effluent because the municipality has not defined specific discharge limits. However, City X will eventually enforce industrial effluent standards and the facility will ultimately have to treat its effluent. Improvements to operating practices will reduce the loading to a future treatment facility and substantially
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reduce capital and operating costs. Now is a good time for the facility to standardize and optimize operations, so that future treatment system can be sized appropriately.

The facility will eventually need to manage the ash/sludge from the 2 m³ retention basin for the boiler stack scrubbers. This ash may have some heavy metals and should be analyzed for toxic characteristics to determine the most appropriate disposal option.
There are several recommendations in this report that can be implemented in the short-term and provide valuable savings in production costs. As Plant X expands its operations, the recommendations will inevitably become more valuable. Developing a plan to institute the various recommendations over time and with appropriate testing and evaluation is the most important next step. The following action should be taken after reviewing this study:

< Establish core group of operations staff to review and evaluate options provided. Assign responsibilities for following-up with goals and objectives defined after reviewing report.

< Evaluate data and calculations based on plant operations. Determine if any information was misconstrued or not provided and make appropriate adjustments.

< Prioritize the recommendations by the ability to implement (the report authors propose one way to prioritize- we recognize, the facility is the best to interpret this list). Assign staff different recommendations to follow-up on to obtain vendor bids and determine technical and economic feasibility of options.

< Develop an implementation schedule based on the results from the previous action.

< Solicit operator input on the selected recommendations and changes to the operations, so that all employees can present ideas and provide input.

< Implement recommendations in order of facility defined priority.

< Establish routine auditing procedures to ensure that standard operating practices are adhered to. Rotate responsibility of auditing between all process operators.

< Continuously evaluate operations to determine ways to increase productivity and reduce materials, water and energy use.
Track the requirements of the municipality in establishing water effluent requirements. Be prepared to implement wastewater treatment system, as required.