A World of Ideas : Technologies for Sustainable Cotton Textile Manufacturing

Source: Cotton Incorporated

Image Courtesy: acus.org

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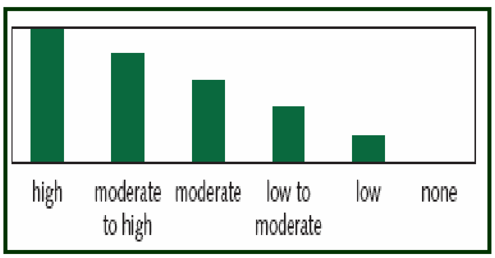
Cotton Incorporated conducted a survey and has come up with an exhaustive report (on following five categories) on the world ideas for technological development. This article provide an insight in the technological ideas of processes, dyes and chemicals, equipment, and control systems in textile industry adapted world over, that significantly reduce WEC requirements.

Reduction of the WEC environmental footprint is best achieved in fabric preparation, dyeing, and finishing processes. Water is an especially important focus, because reduction of water use brings corresponding reductions in the energy required to heat water and, to a lesser extent, the amounts of chemicals and dyes used. The cotton textile industry can reduce the WEC environmental footprint at least 50% by employing technologies currently used in modern plants located in the world's major textile production regions. The plants that are the most advanced in reducing WEC pursue a combination of options, including high-efficiency management practices, process control, special processes, and higher-cost machines especially designed for low use and internal recycling of water and chemicals.

The technologies fall into the following five categories:

1. Process
2. Chemicals and dyes
3. Equipment
4. Systems, control, and management
5. Wastewater treatment



But we here would be focusing only 4 categoryies namely Process, Chemicals and dyes, Equipment, Wastewater treatment.

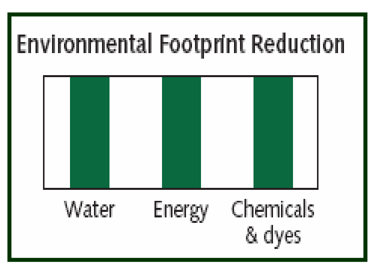
Each technology is described briefly, with emphasis on commercial operating experience as reported by the companies surveyed.

The survey also assessed the following factors:

- Each technology's potential for reduce the use of water, energy, and chemicals (WEC environmental footprint reduction). Survey respondents rated each of these factors as low (less than 25%), moderate (25% to 50%), or high (more than 50%).

PART 1: Technological advancement in process

1) Cold Pad Batch Preparation and Dyeing Continuous Processing of Knits



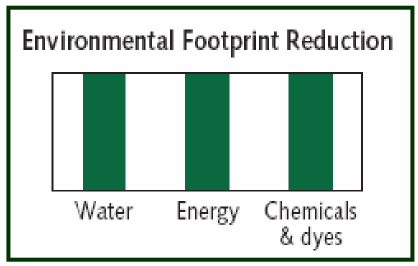
The cold pad batch (CPB) system uses roller-pad application of highly concentrated chemicals and dyes during fabric preparation and dyeing stages, followed by room-temperature lagging of the impregnated fabric on the beam. Scouring or dyeing actions are accomplished effectively during this low-temperature lag time. Compared with conventional processing, the CPB system reduces reliance on large volumes of heated water for application of chemicals and dyes. Furthermore, no salt is required for reactive dyeing. The classic CPB system has undergone significant changes since its development during the early 1960s, through continuing coordination of research and development on chemicals and dyestuffs, dyehouse control processes, and equipment.

Commercial Operating Experience

The CPB system is fully proven for preparation and dyeing of wovens and knits, and accounts for a growing percentage of global capacity for wet processing of cotton textiles. Although billions of pounds of fabric have been processed with this technology, there remains great potential for expansion, especially in knits. In addition to providing large savings in WEC, CPB processing improves knit surface aesthetics — surfaces typically are smoother and cleaner than those of jetdyed fabrics. Preparation and dyeing processes are a function of time, temperature, and pH. Because CPB processing occurs at room temperature, the reaction takes longer than under the higher temperatures used in jet processing. Although the dwell time for the CPB process is extended, staging of batching rolls in a separate area frees the pad for additional applications. The share of fabrics processed by CPB is about 2% in Asia and over 30% in Europe and the Americas. Increased adoption of CPB for knits is expected as emphasis on reduction of WEC continues, energy costs increase, and machinery innovations further improve knit handling in continuous processing.

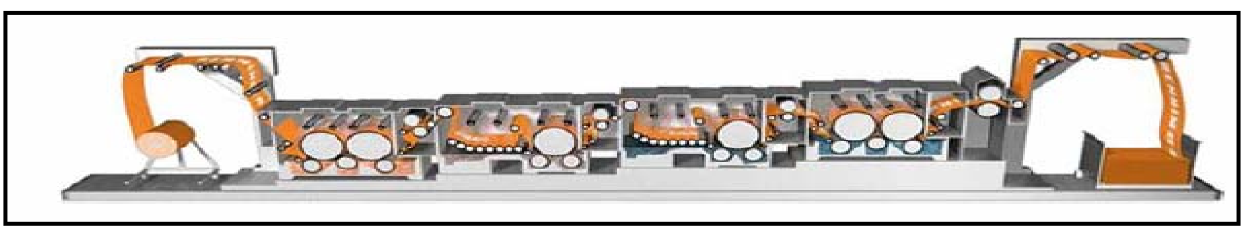
2) Continuous Processing of Knits

Continuous processing technology, widely adopted for woven fabrics, has now been refined for use with more delicate (tension-sensitive) knitted fabrics. Processes have been developed for continuous scouring, bleaching, mercerizing, de-watering, dyeing, and finishing of flat and tubular knit fabrics. Technologies include advanced chemical and dye application systems, minimum tension provision, creaseless fabric passage, and advances in drive, control, heating, and extraction systems. Continuous processing of knits delivers major reductions in WEC, as well as increased productivity.



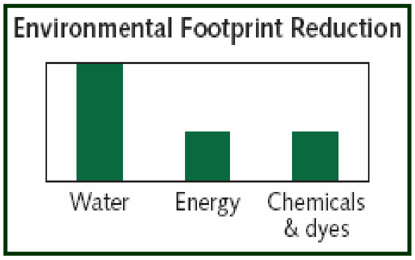
Commercial Operating Experience

Continuous processing of knits has been available commercially for years, but is used for only a small fraction of all knits. However, interest in continuous processing of knits is increasing, especially because of the potential WEC reductions and cost savings, and as a result of advances in controls and equipment. Woven fabrics generally are wet processed continuously, especially when the volume of fabric to be processed is high enough to support an economical run time. Even accounting for the water required for sizing and desizing of wovens, continuous wet processing of wovens typically requires less than half as much water as batch-processing of knits. Continuous processing can reduce processing time and increase productivity more than tenfold over batch processing. Operating costs can be reduced by 30% to 40%. Furthermore, continuous processing tends to provide a cleaner, smoother fabric surface than batch processing. However, to be economical, continuous processing requires larger lot sizes (over 10,000 meters). Adoption of continuous processing will require training, and operators and management will



need to gain experience with the technology. Issues to be addressed in continuous processing of knits relate to tension control to maintain fabric weight, quality, and uniformity.

3) Two-Stage Preparation of Wovens



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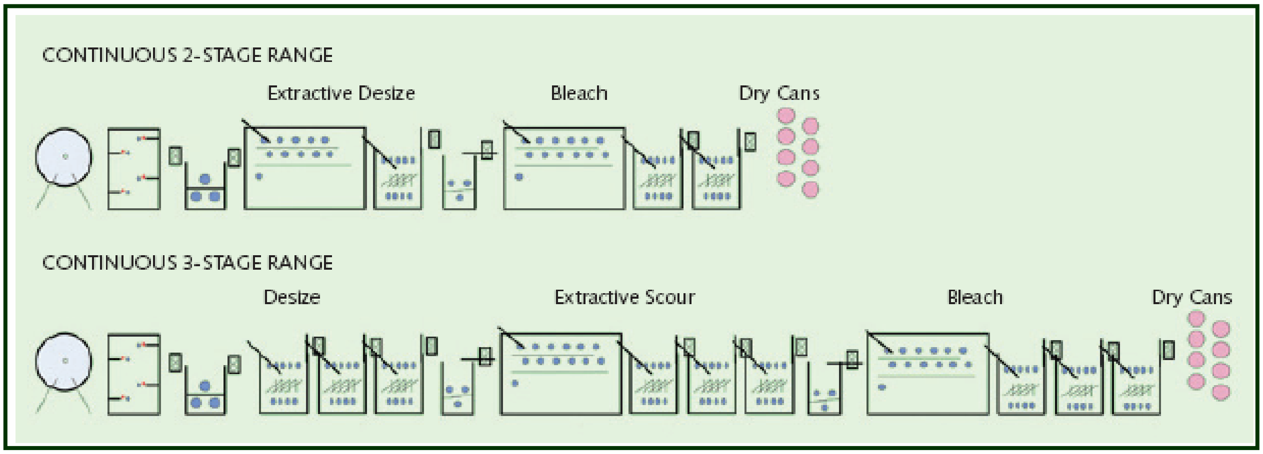
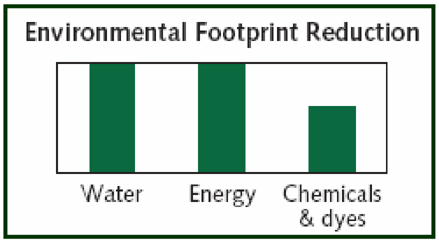


4) Combined Scour and Bleach for Yarns and Knits

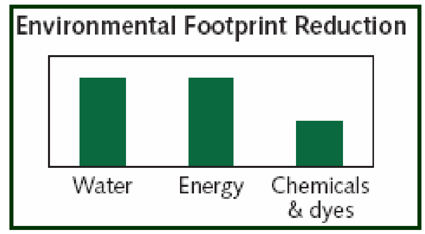


Advances in chemistry have enabled the use of a single bath, rather than separate baths, for scouring and bleaching of cotton yarns and knits, depending on the specific processing equipment and final product requirements. The key to success is achieving compatibility of the bath conditions, such as temperature and pH, and the chemical components of the bath.

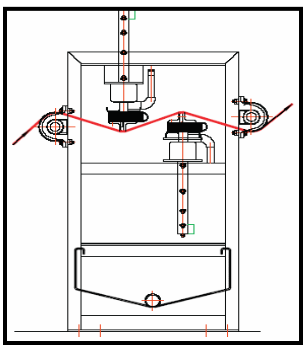
Commercial Operating Experience

This technology is widely used and is now considered standard practice in most yarn and knit wet-processing mills. No special equipment is necessary, and most major dye and chemical vendors offer formulations that are designed for combined scouring and bleaching. A mill may encounter some very critical shades, generally light or pale, that still require separate scouring and bleaching, but this is the exception, not the rule.

5) Foam Dyeing, Finishing, and Coating



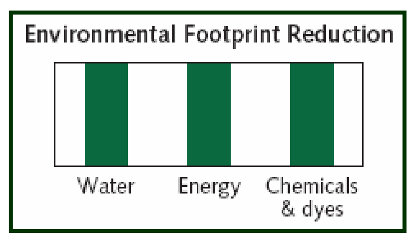
Foam application of process chemicals, in place of conventional systems of dip tanks, sprays, pad mangles, and suction boxes, enables the uniform application of aqueous functional chemistry to cotton fabrics with less than half the water required by conventional systems. Although the technology has been available for many years, major advances in formulation chemistry, foam generation, and application control have been made over the past decade.



Commercial Operating Experience

Foam application technology has been commercially available for over 25 years, but implementation was limited until the past 5 to 10 years, during which time mill adoption has increased significantly in efforts to reduce WEC and operating costs. This growth has been supported by advances in foam chemistry and systems from a number of vendors. Foam systems are used for knits and wovens, including denim, for pigment dyeing, finishing, and coating. The low moisture content of the foam application results in faster drying, enabling a significant increase in production. Because foam places the solution only where required, single-sided or dual-sided applications are possible. For example, in the case of functional finishes, one side of the fabric can be treated to be hydrophobic and the other side to be hydrophilic. Application of ionic dye systems has been explored but is not yet commercially proven, because of issues with dispersion and foam stability.

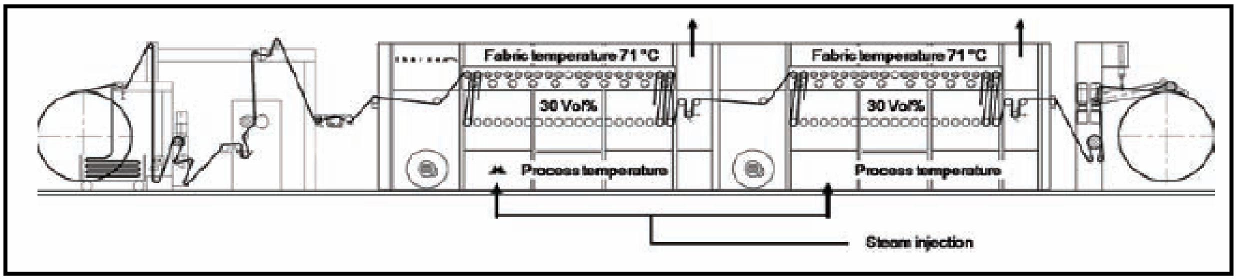
6) Pad/Dry vs. Pad/Dry/Pad/Steam



This technology is aimed at replacing the conventional continuous pad/dry/pad/ steam process typically used for reactive dyeing of most cotton wovens. The new process accomplishes dye application and fixation in a much simpler pad/dry step, without the use of salt, generally by means of controlled, high-humidity drying. This technology offers huge potential savings in WEC and operating cost, as well as gains in productivity.

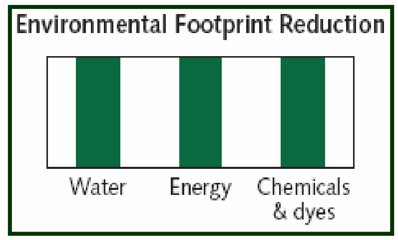
Commercial Operating Experience

The largest current commercial implementation of this technology is based on the Monforts/DyStar Econtrol technology, equipment, and dyes. Mills report successful operation and achievement of WEC-reduction and cost-reduction goals. This flexible technology is applicable to both knits and wovens, 100% cotton and cotton blends. The unit can be adapted for preparation, dyeing, and finishing. Quick changeover capabilities allow the machine to be switched from one shade to another in less than ten minutes. No steamer is required for fixation, and dwell times are significantly shorter than with conventional continuous systems. Growth of this technology has been slow because of the large capital investment required. Some mills have been investigating the possibility of retrofitting existing equipment. The continuing pressure to reduce WEC and operating costs, together with continuing industry exposure to this technology, will likely lead to increased implementation.



7) Right First Time Dyeing

The "right first time" (RFT) approach to dyeing requires management, supervisors, and operators to focus on close measurement and follow-up of all aspects of the production system to ensure that each step is operating as specified. Goal-oriented product specifications are met on first-pass processing, so material is not held in process for dye additions or rework dyeing. Rapid corrective action is taken when any defect is identified in the process or product. Operator and technical teams define and implement longer-term solutions to more frequently occurring breakdowns or disruptions in the process.



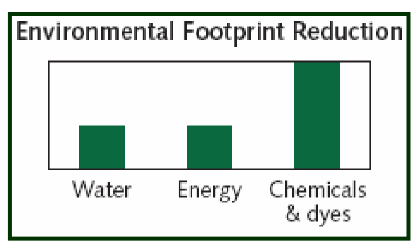
Commercial Operating Experience

The RFT approach has been used commercially for many years, becoming more common in the mid 1990s. It is well proven, especially for larger-volume, multiple-batch products. This approach requires a commitment to establishing lab-to-production correlation, color communication between production staff and the customer, and line-operator training. Other requirements are well-maintained equipment, process controls, and a managed dyestuff/chemical inventory. Some mills report achieving RFT with over 95% of dyeings.

PART 2: Technological advancement in Chemicals and dyes

1) Cationization for Salt-Free Dyeing

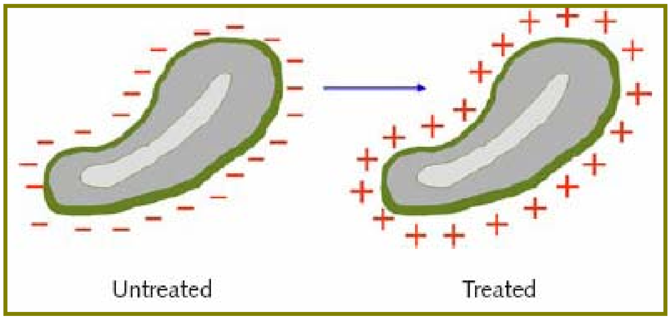
Cationization is the chemical modification of cotton to produce cationic (positively charged) dyeing sites in place of existing hydroxyl (-OH) sites. This enables the cotton to easily attract anionic dyes (direct, fiber reactive, pigment dispersion, and acid) without the need for large quantities of salt. Currently, reactive dyes are used for over 70% of all cotton dyed, and salt requirements have increased to over 20 billion pounds per year.



Commercial Operating Experience

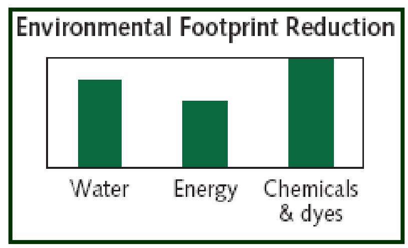
This technology has been available for many years and is being used commercially in a number of mills for dyeing yarns, knits, wovens, and garments. However, implementation remains at a relatively low level, for various reasons:

- Low fixation of cationic agents by exhaust methods can increase chemical and processing costs.
- Cationic cotton requires some modification of existing dyeing procedures.
- Production of seconds may be high until a mill has substantial experience with the process.



Cationization eliminates the salt requirement for reactive dyeing and increases dye color yield. However, application of the cationicagent requires an additional cycle similar to that for a typical reactive dye (though with fewer rinsing steps), and alkali is required for fixation. Dye selection is critical, as some dyes work better with cationic cotton than others. Selection can be limited by requirements for color, depth of shade, and fastness (especially light-fastness). For safety reasons, the cationic agent should be applied in a closed system. This technology has very high potential impact — the amount of chemicals required to dye cotton textiles can potentially be reduced by as much as 50%. Further research and development continues to refine the application process and improve product quality.

2) High-Fixation Reactive Dyeing with Reduced Salt

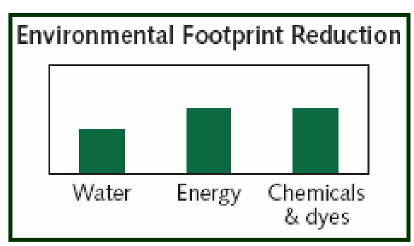


Reactive dyes account for over 70% of the dyes used for cotton. Large quantities of salt are needed to exhaust the reactive dyes onto the cotton, and the fixation rate for reactive dyes is often less than 80%, resulting in waste of dye. Removing the unfixed dye requires time, water, and energy in post-dyeing steps. Dye suppliers are now offering improved dyes (often proprietary) that enable much higher exhaustion with lower salt use (less than half the salt required with standard reactive dyes) and higher fixation rates (85% to 90%). These products usually incorporate two reactive groups, such as vinyl sulfones or chlorotriazines. Some vendors are offering a new alkali chemistry to boost fixation and reduce salt.

Commercial Operating Experience

Much progress has been made in commercializing higher-fixation reactive dyes for dyeing yarns, wovens, knits, and garments. Some mills have been able to boost their average fixation rates from below 70% to over 85%. Fixation rates over 90% have been reported. However, these higher-value dyes often are more expensive than conventional dyes, and mills may not be confident that the dyes will pay for themselves through savings in dyes, chemicals, water, and energy. Implementation should increase significantly as mills gain further experience and confidence that these new dyes do deliver savings in WEC reduction and mill cost. These dyes have higher affinity for cotton fibers than conventional reactive dyes, which can make it more difficult to achieve level dyeing. Because of their high substantivity, more water may be required for removal of hydrolyzed dye. Salt requirements have been reduced, but more progress is needed.

3) Enzyme Treatment

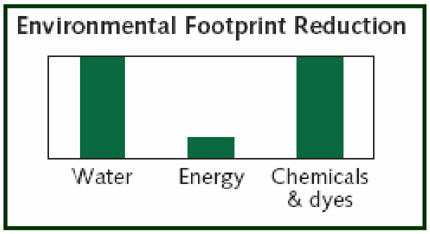


Enzymes have found a major role in the textile processing of cotton, from desizing, scouring, and bleaching to special effects and wet finishing. Industry experience with enzymes has grown rapidly in the past 10 years, promoted by ongoing research and development.

Commercial Operating Experience

Enzyme technology is being used widely, in most mills and in various applications. The technology is being applied to all textile forms and in most types of processing equipment, both continuous and batch. Mills have reported savings in water, time, chemicals, and energy, as well as in achievement of special product effects. The most widespread use of enzymes is in desizing, but scouring with enzymes is gaining favor with the industry. Because enzyme scouring will not remove all of the natural oils and waxes that a conventional scour removes, it leaves the fabric somewhat yellow. This is acceptable for fabric that will be dyed in medium to heavy shades. Furthermore, enzyme-scoured fabrics usually have a better hand. Enzyme technology is being used to some extent in finishing, especially for removal of surface fibers from denim dyed with indigo, to mimic the look of stonewashing, or to destroy the indigo dye, for a bleaching effect. Use of enzymatic treatment in place of stonewashing can reduce solid effluent. Enzymes are also used on knit fabrics and yarns in a process referred to as “biopolishing,” to remove short fibers that contribute to surface fuzz, which affects the appearance of garments and contributes to a perception of color loss. Bio-polishing may reduce fabric strength and weight but will improve the appearance of a garment through repeated home laundering cycles.

4) Size Recovery and Recycling via Ultrafiltration



Scouring and desizing account for 60% to 65% of the wastewater treatment load for cotton textile processing, and the sizing agent used to prepare warp yarns for weaving accounts for over 10% of total chemical consumption. Starch and most modified starches, which account for over 75% of sizes used, are not readily recovered with available technology. Other sizes, such as water-soluble polyvinyl alcohol (PVA), polyacrylates, carboxymethyl cellulose (CMC), and carboxymethyl starch, can be recovered by currently available commercial ultrafiltration systems and reused. Recovery technology continues to improve. For non-recoverable sizes, some progress is being made in using the size-containing sludge from the wastewater treatment system as fuel.

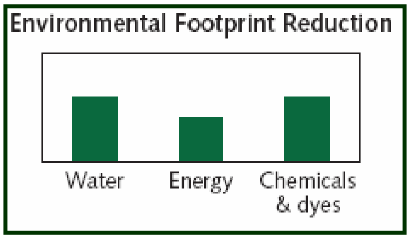
Commercial Operating Experience

Some large cotton textile mills around the world have successfully implemented ultrafiltration systems for size recovery and reuse. Although recovery and reuse of size shows great promise for reducing the environmental impact of cotton textile processing, industry adoption of recovery systems has not reached its full potential. Economics and environmental regulations that provide incentive for implementation of size recovery and recycling vary from region to region. One challenge to implementing size recovery and recycling is the common use of nonvertical, nonintegrated processing systems, where the wet-processing mill receives the sized fabric from a separate weaving mill, often located elsewhere.The operator of the wet-processing mill may not even know what size is used on the fabric, nor have a way to return recovered size to a weaving mill for reuse.Nonintegrated mills must solve both the system/ management issue and the process engineering issue. Fully integrated mills face less of a challenge. Unlike biodegradable sizes (such as starch), watersoluble nonbiodegradable sizes (such as PVA and CMC) do not increase the biological oxygen demand load on wastewater treatment. However,they do enter downstream waterways, so mills should make every effort to remove this material from the waste streams at the plant level.

5) Pre-reduced Liquid Dyes

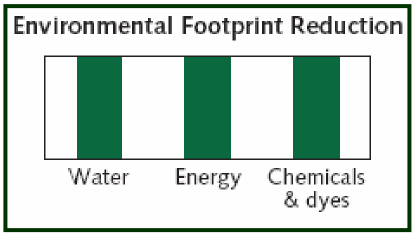
Sulfur dyes, indigo dyes, and other vat dyes must be solubilized by reduction chemistry before being applied to the textile substrate. Reduction is followed by an oxidation process to re-form the pigment in situ and develop the final color. Dye suppliers have developed offerings of pre-reduced liquid colorants for these applications, which provide significant environmental advantages for mills. Problems of handling the reducing agents, controlling the reduction process, and managing the reaction byproducts (such as hydrogen sulfide) are avoided, and WEC savings are realized.

Commercial Operating Experience



This technology is widely adopted, especially for indigo dyeing of denim fabrics. Mill experience has been good,
and WEC reductions have been achieved. Sulfur dyes, indigo dyes, and other vat dyes account for 20% to 25% of
dyes used for cotton textiles. Adoption of pre-reduced liquid dyes to replace conventional mill-based reduction processing is expected to continue. Best handling practices for these liquid dyes may require capital investment in metering and monitoring systems for process control and lot-to-lot repeatability. Additional reductions in WEC may be achievable through the use of alternative reduction chemistry, such as sodium borohydride, which can be more efficient than sodium hydrosulfite and have less impact on water quality in terms of biological and chemical oxygen demand and total dissolved solids.

6) Pigment Pad Application



Advances in the manufacture of pigments, which are processed into small particle sizes, together with improvements in pigment support chemistries, have greatly improved the appearance and fastness of these dyes. Furthermore, significant advances in finishing technology allow pigment padding and resin application to be combined, producing excellent results in shades up to medium depths for woven fabrics. This system is attractive because no steam fixation or after-washing is required following color application.

Commercial Operating Experience

This technology is used in high-volume applications, especially for pale shades and where softness and color-fastness requirements are less stringent. However, the technology has advanced to the point where it should be seriously considered for many other applications.

Successful implementation of this combined dye/finish process requires the following equipment:

• dye pad or foam applicator for recipe application
• infrared pre-dryer
• multizone tenter frame

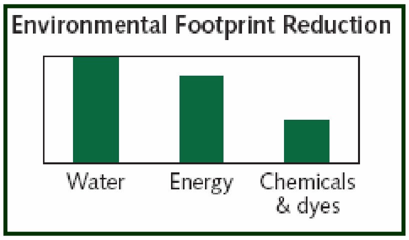
Included in a typical recipe:

• pigment dyes of choice
• a pigment binder
• a special antimigrant system
• a compatibilizing surfactantsystem
• DMDHEU resin
• finishing softeners
• a resin catalyst system

The very high potential environmental and cost benefits should promote expanded opportunities to apply this technology in end uses outside conventional pigment applications.

PART 3: Technological advancement in Equipment

1) Low-Liquor-Ratio Jet Dyeing Machines



Jet dyeing machines typically are based on the principle of accelerating water through a venturi constriction (or nozzle) to transport fabrics. They are designed to operate efficiently and at high quality with a very low ratio of water to material. In addition to dyeing, these machines are used for preparation and other wetprocessing steps. Jet dyeing machines have been used commercially for 40 years. Machines of newer designs operate at a liquor ratio of less than 8:1. These machines usually incorporate low-friction Teflon internal coatings and advanced spray systems to speed rinsing. “Ultra low liquor ratio” jet dyeing machines operate at a liquor ratio of less than 6:1 and almost always depend on forced airflow to convey the fabric through the machine.

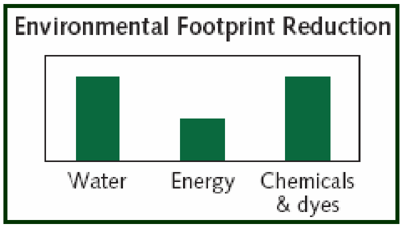
Commercial Operating Experience

Low-liquor-ratio (LLR) jet dyeing is widely used in high volume for piece-dyed knits, as well as some wovens, depending on fabric weight. Compared with conventional higher-liquor-ratio machines, LLR machines usually enable reduced cycle times and increased productivity, while requiring less than half as much water:

• Some plants achieve four batches in 24 hours (depending on depth of shade).
• Some plants achieve real average water consumption of less than 50 liters per kilogram of knit fabric.
• Some plants using the newest airflow technology machines report processing with liquor ratios of less than 4:1.

One factor limiting implementation is the high cost of the new machines, which favors use at new facilities rather than as replacements for older machines. In addition, it can be difficult to achieve uniformity through the fabric with some shades (such as khaki, olive, or beige).

2) Low-Liquor-Ratio Package Dyeing

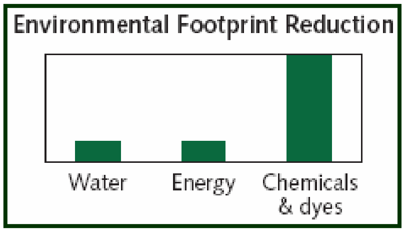


For package dyeing, liquor ratios of 8:1 are common. State-of-the-art yarn package dyeing technology enables reduction of the liquor ratio to less than 6:1. This canbe achieved either with new machines or through retrofitting of existing machines. These LLR machines use more sophisticated liquor circulation systems to promote levelness and repeatability.

Commercial Operating Experience

A number of mills have reported achieving liquor ratios of less than 6:1, both with new machines and with retrofitted machines. Specific retrofitting designs are proprietary. LLR machines can shorten process time significantly, by reducing fill time and the volume of water to be heated. Water and energy consumption can thus be reduced by up to 40%. Lower water levels also result in reduced use and discharge of chemicals.

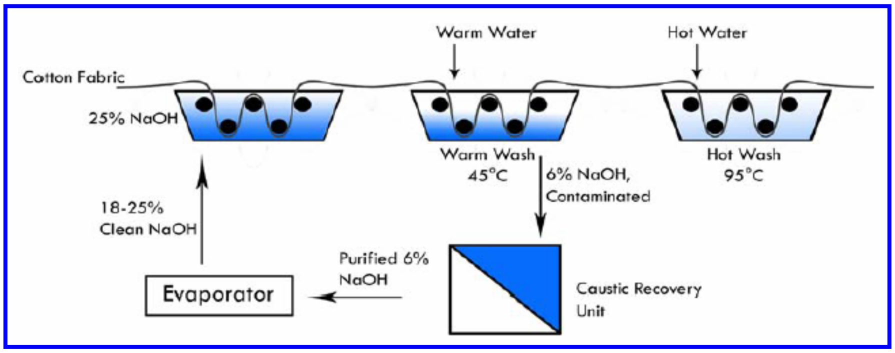
3) Caustic Recovery and Reuse



This technology involves (1) multi-stage evaporation to concentrate the caustic solution and (2) filtration to clean the caustic solution for reuse. Conventional rotary filters or more advanced microfilters may be used, depending on requirements for the recovered caustic solution. Other approaches to reusing residual caustic include the following:

• Using the weak caustic stream to adjust pH in non-process water (for example, in wastewater treatment) or to neutralize combustion gases.
• Selling waste or weak caustic solutions to outside manufacturers (such as electroplating operations).

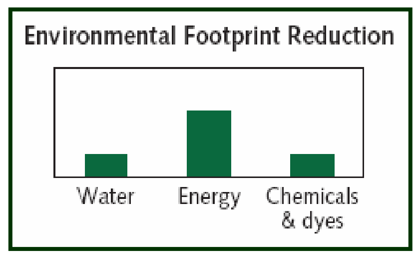
Commercial Operating Experience

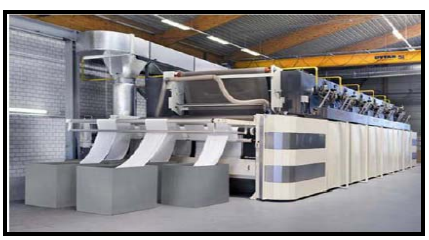


This technology is commercially proven and used widely in processing of yarn, knits, and wovens. Some mills have successfully recovered and reused over 80% of caustic. Recovery is most successful from the mercerization range if mercerization is performed after bleaching, because fewer contaminants are present. For denim processing applications, improvements are needed to optimize the technology to deal with the indigo present in the waste caustic stream.

4) Insulation of Dyeing, Drying, and Tenter Machines

State-of-the-art dyeing machines and dryers are insulated for energy-efficiency. Older heated machines can be covered with low-thermal-conductivity coatings, foam, or board materials. Many varieties of materials are available from the chemical industry and have been adapted to textile machines. Many of these materials and coatings also provide corrosion resistance, for longer machine life. Technological advances have enabled efficient and effective application of sprayedon insulating materials to almost any processing equipment or piping system.



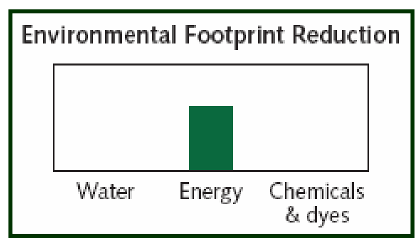


Commercial Operating Experience

This technology has been used for decades in chemical industries of all types and can be applied in many mill applications and with many types of textile-processing equipment. Operating costs typically are decreased by 5% to 10%. Insulation is especially effective with jet and other batch wet-processing machines that operate for long periods at high temperatures.

5) Solar Heating of Water

Solar heating panels are widely available for commercial installations, for both horizontal and vertical surfaces. The technology is well established and is undergoing another generation of improvement for higher efficiency and lower cost.



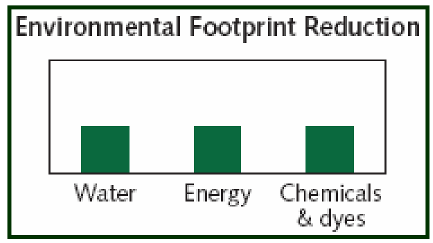
Commercial Operating Experience

Solar heating is already widely used, in both home and commercial installations, in some major textile manufacturing countries and regions, including China and Turkey. Solar heating is commonly used in wet-processing mills as a first stage, to preheat process water. To be effective, solar heating requires a large collector surface area. An emerging solar-energy technology involves embedding heat exchangers in parking-lot asphalt.

PART 4: Technological advancement in Systems, Control, and Management

1) Automatic Dye and Chemical Dispensing

This technology involves automatic and semi-automatic weighing, dissolving, and measuring systems for precise delivery of textile chemicals and dyes to production machines, as well as to laboratory machines for shade and sample development. Systems are available for dispensing of both liquid and powder chemicals and dyes. Mills can choose various levels of automation, from quantitative dispensing systems for preparation chemicals and/or dyes to simpler semi-automatic addition systems for manually prepared solutions.

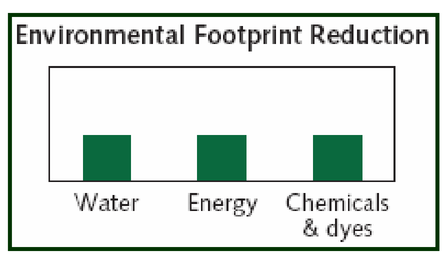


Commercial Operating Experience

Fully automatic dispensing systems are most common in laboratories, for color development and sample preparation. In mills, semi-automatic addition systems are more common, but automatic dispensing systems are used in larger and more modern mills, especially for batch dyeing of yarns and knits. These systems improve the accuracy of material additions and the consistency of production, while reducing waste in dyes and chemicals and in off-standard products.Automation of dyes and chemical dispensing can significantly improve Right First Time performance, as well as lot-to-lot shade reproduction.

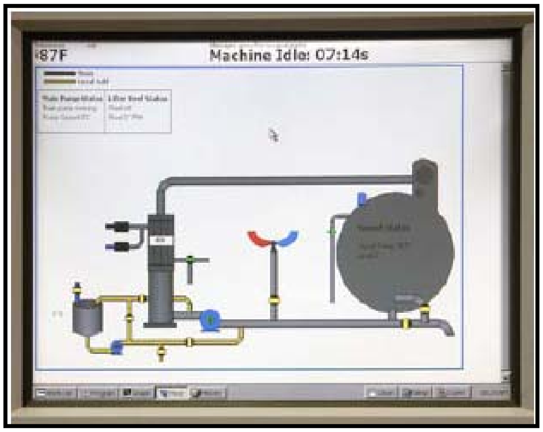
2) Advanced Equipment and Process Control

Advanced automatic control strategies and systems can be incorporated into metering and application of chemicals and dyes to flat goods, as well as machine rate control and temperature profile control for preparation, dyeing, drying, and finishing operations. These systems can also be used to track pH, water flow, and energy (steam) use, to store procedures, and to track changes, to enhance reproducibility of processes.



Commercial Operating Experience

Mills that have applied improved control technology, from basic control implementation and maintenance to more sophisticated advanced process control, have reported reduced cost and WEC consumption, along with substantial gains in productivity and quality:

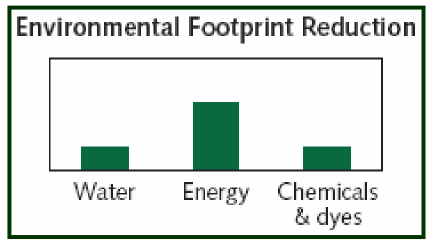


• Simple controllers, such as retrofitted frequency controllers on motors, provide attractive cost reductions and returns on investment. Many mills have already installed frequency controllers that can reduce energy consumption by over 25%.
• Advanced controls, based on microprocessors that enable feedback control of most process parameters (including pH, temperature, flow rate, and concentrations), offer enhanced control over all mill processes.

Individually, process control improvements may provide relatively low WEC and cost reduction, but in aggregate, they make significant contributions, typically with high financial return and quick payback. Mill investment includes both initial installation and ongoing maintenance of the controllers. Most of these advanced control technologies usually are preinstalled in new equipment. Although process measurement and control capability has been well established in a wide range of commercial applications, the benefits need to be evaluated in specific targeted situations.

3) Various System Approaches to Reduce WEC

A number of mills have reported applying various system concepts to substantially reduce consumption of water, energy, and chemicals. The examples listed here generally require low to moderate investment to recover heat from water or air streams or simply to adopt a new approach to material handling.

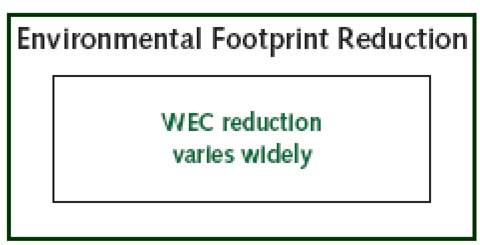


Commercial Operating Experience

• A number of mills have reported fairly simple retrofitting of piping and installation of heat exchangers to recover and reuse heat from exhaust air streams and waste process water.
• Mills have reported using weak and waste alkali streams to adjust pH in wastewater treatment and to neutralize acidic combustion gases. Others have found opportunities to sell weak alkali solutions to outside businesses in the
local area (such as electroplating operations).
• Denim mills are using ultrafiltration systems to recycle indigo from residual baths.
• Mills in China and India have reported using biofuels and eco-fuels for boilers, and some have reported selling sludge from wastewater treatment as a fuel.
• Some mills have developed opportunities to sell coal ash as a component of concrete, and some use it themselves for this purpose. This application is approved in the United States by the Concrete Manufacturers Association.

4) Empowered Environmental Teams

Teams of technical, supervisory, and operating personnel are established to drive improvement in the operation's performance, costs, and product quality. Environmental improvements to reduce water, energy, and chemical consumption can be set as a special focus. Teams can also identify frequently occurring breakdowns in the process and prioritize addressing them. Teams can reach out for the expertise required to develop long-term solutions to these breakdowns, and recommend investment as required.

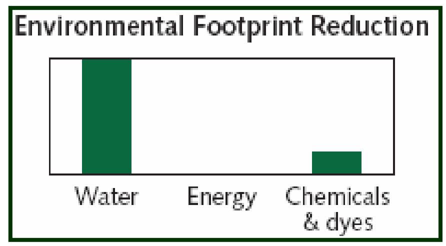


Commercial Operating Experience

This approach to reducing WEC consumption is being used successfully in many mills, from small to very large and across all textile-manufacturing segments. It has been used to steadily improve product quality against rising customer standards and to reduce waste and costs against rising production standards. This approach appears to be most effective in identifying opportunities requiring smaller investments, where final decision makers are close to the teams, and the teams have strong and consistent management support. Implementation of training programs such as Six Sigma Black Belt can greatly enhance the effectiveness of these teams.

PART 5: Technological advancement in Wastewater Treatment

1)High-Technology Filtration Systems

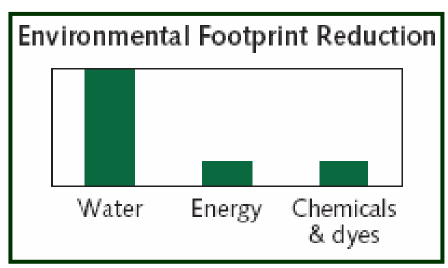


Conventionally, water coming into a textile manufacturing plant is filtered to remove contaminants. Significant water savings can be achieved through the use of advanced filtration systems to filter and recycle wastewater, in both industrial and municipal wastewater treatment plants. These systems are based on the appropriate use of high-technology micro, ultra, nano, and reverse-osmosis filters. Systems are designed for the specific fine particles, molecules, ions, or pathogens that must be removed. Most installations use stages of filters, each with finer porosity, to selectively remove materials.

Commercial Operating Experience

High-technology filtration systems are commercially proven to meet a wide range of filtration requirements. Applications include ultrafiltration for size recovery; ultrafiltration and reverse osmosis for bleaching and scouring process streams; ultrafiltration and evaporation for mercerizing streams; and ultrafiltration and reverse osmosis for dyeing streams. Depending on technology used, up to 95% of water can be recycled, and zero discharge is considered feasible. Some high-technology filter systems offer self-cleaning capability, to extend the life of the filter. Current installations typically are in regions where water availability is restricted or increasingly threatened.

2)Recycling of Internal Process Water



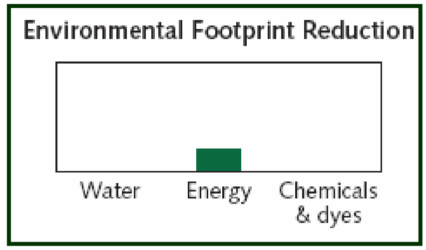
Water currently discarded after one use can be re-piped into process vessels for reuse one or more times. The recycle stream can be used directly, with or without dilution with fresh water. Recycling of water can also be combined with recycling of heat.

Commercial Operating Experience

Recycling of internal process water has been commercially proven in many plants. For example, in-plant water recycling has been used for these purposes:

• Counter-flowing water from the last washboxes to the first washboxes of a continuous range.
• Capturing water from bleach rinsing to use as make-up water to reconstitute the bleach bath. This allows recovery of caustic and surfactant, thus saving water and chemicals. (A holding tank may be required.)
• Recovering the heat from recycled process water by means of heat exchangers.Successful implementation of in-plant water recycling may require some additional adjustments:
• Process adjustments to accommodate the use of less-pure water.
• Chemical neutralizations or pH control.
• Additional product quality checks.
• Monitoring of discharge water for color and for biological and chemical oxygen demand

3) Use or Sale of Wastewater Treatment Sludge for Fuel



Dry sludge retrieved from the wastewater treatment facility can be consolidated and burned in the plant boiler. In addition, local markets for sludge as fuel are growing in both developing and developed economies.

Commercial Operating Experience

Use of sludge from wastewater treatment is increasing in China and India. Sales or use of sludge for fuel typically more than offset the added costs for consolidation and retrieval.

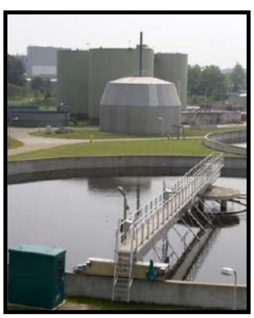
Use of sludge as fuel requires certain environmental precautions:
• Release of emissions-restricted gases into the atmosphere must be avoided.
• The sludge must be free of metals, to avoid release of metal oxides or other hazardous by-products.
• Stack gas filters or segregation of some chemicals from the sludge may be required.

4)Physical, Biological, and Activated-Carbon Systems

Environmental Footprint Reduction

No WEC savings, but improves quality of water returned to the environment

Current individual plant, industrial park, or community wastewater and sludge treatment installations can be upgraded with additional processing steps based on physical, biological, and activated-carbon technologies. These technologies are well established and can be engineered and sized to the specific requirements of the effluent streams.



Commercial Operating Experience

These technologies are used broadly in a wide variety of municipal and industrial venues and applications, and are applicable to all textile manufacturing installations. They reduce color, toxicity, chemical oxygen demand, and biological oxygen demand of water returned to the environment. Commercially available technologies include the new anaerobic/aerobic biomass degradation systems.