An Alternative for Textile Wastewater

Treating for reuse often is more cost effective than treating for discharge.

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Most of a textile mill's process wastewater is pretreated for discharge either to publicly owned treatment works (POTW) or to a stream. But in many cases it may be cheaper to treat the water for reuse rather than for discharge.

The dyeing and finishing of textile fibers, yarns and fabrics require large amounts of process water of suitable purity (see Tables 1 and 2). The estimated total wastewater discharge from textile plants engaged in wet finishing is 625 million gallons per day.

As a result of federal and state environmental regulations to become effective within the next few years, many textile mills are faced with capital expenditures for treatment or pretreatment facilities to meet new effluent guidelines and discharge limitations.

An Alternative

The treatment of process effluents for reuse is an alternative approach that can offer savings of energy, water and chemicals. Various textile wet processes are influenced in different ways by the presence of impurities in the water supply. There are several major water use categories to be considered, including water for processing, potable purposes, utilities and laboratory use. Each requires different water quality parameters.

Process water uses include preparation, dyeing and finishing, concentrated bulk chemical dilutions, stock solutions, mix-kitchen use, substrate treatment solutions (bleach, dyebath or finish mix) and washing.

Utility uses include cooling water, boiler and humidifier systems, equipment cleaning and more. Laboratory water has special requirements in many situations, and these usually are met with additional water purification in the lab itself.

Washing is one of the largest users of water in textile wet processing, particularly in preparation and dyeing. Because many washing processes are continuous, well-known techniques such as countercurrent washing can be used to conserve water.

Different types of dyeing machinery use different amounts of water. There are many dyeing machines with lower liquor ratios that are designed to save water (see Table 3).

Table 1: Water Used In Textile Wet Processing

Substrate Type	Average Amount of Water Used (gal/lb of Product Produced)
Wool	34.1
Felted Fabric	25.5
Woven Other	13.6
Yarn and Stock	12
Knit Other	10
Hosiery	8.3
Carpet	5.6
Nonwoven	4.8

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Table 2: Water Volumes Used in Cotton Processing

Process	% of Cloth Treated	Water Consumption (gal/lb)	% of Water for Rinsing
Desizing	95	35	90-95
Scouring	100	63	80-90
Bleaching	100	63	50-90
Mercerizing	35	55	85-95
Dyeing	50	278	50-95
Printing	14	28	80-95

Table 3: Water Use

Dyeing Machine	Water Consumed (gal/lb)	Liquor-to-Goods Ratio
Continuous	20	1 to 1
Beck	28	17 to 1
Jet	24	12 to 1
Jig	12	5 to 1
Beam	20	10 to 1
Package	22	10 to 1
Paddle	35	40 to 1
Stock	20	12 to 1
Stein	30	17 to 1

Common Impurities

While some impurities adversely affect certain dyeing and finishing processes, others can exist at moderate levels. A few of the critical impurities are discussed below.

Color

Color from residual dyes in process water generally is critical in most wet finishing processes. Exceptions may include the dyeing or rinsing of heavy or dark fabrics where residual color has a negligible effect on the ultimate shade.

The nature of the color-producing dye also determines the tolerable color level. For example, basic dyes are a particular nuisance because they have a high tinctorial value and can stain most fabric types. Pigmented or insoluble colors (vat and sulfur dyes) have much less tendency to redeposit on fabric.

Oxidizing or Reducing Agents

Common oxidants used in textile processes include hydrogen peroxide, hypochlorite and other bleaching agents. Reducing agents include sodium hydrosulfite and sodium bisulfite.

These agents can affect the finished fabric quality as a result of chemical reactions with fibers or dyestuffs. Most can be destroyed by other reducing or oxidizing agents and are thus removed before the water is reused.

pH

Process water pH is a critical factor. This does not however, limit process water reuse because pH can be controlled in the process.

Hardness

Hardness-producing cations, such as calcium and magnesium, form insoluble precipitates with soaps.

These precipitates are sticky, adhere readily to fabric and can result in uneven dyeing. These cations generally interfere with the activity of surface-active agents and some finishing chemicals.

Electrolytes

Electrolytes can be present in recycled water in the form of inorganic salts or other textile auxiliaries.

Anionics cannot be tolerated in process waters used to apply cationic fixing agents to direct dyes. A high salt concentration may cause direct dyes to exhaust too rapidly, resulting in uneven dyeing.

Metals

Certain metals, such as iron and manganese, can affect the shade of dyed fabric or can impart a yellowish tinge to bleached fabrics. Heavy metals also can interact with process chemicals.

Total Solids

The solids content in recycled water will hinder reuse only to the extent that the solids interfere with the dyes or process chemicals. Generally it is not the amount of solids but the nature of the solids that affects the textile process. Dissolved electrolytes can be removed only by costly processes, such as reverse osmosis.

Water Quality Requirements

As long as impurities in the water do not interfere with the process and the fabric performance, the water is acceptable for process use. Recommendations for water quality in specific textile processes have been published. The recommended water quality criteria are rather limiting and are intended to meet requirements for the most critical process or dyeing formulation. They do not necessarily apply to most production needs.

Recent experiences with water reuse in the textile industry indicate that recycled water, having impurity levels above historically accepted limits, can be used to produce first-quality goods. The minimum water quality for process reuse, therefore, is defined as the treated wastewater containing the highest level or concentration of impurities that will consistently produce an end-product of first quality.

A mathematical model, designed to predict the buildup of impurities after repeated reuse cycles, predicts that the impurity level in a single shade reuse sequence remains essentially consistent, even after 10 dye cycles. This seems reasonable because some fresh makeup water must be added during each cycle to replace water lost through fabric drag-out. The ultimate buildup of impurities in a single shade reuse sequence relative to dyebath impurities was predicted to be 3.4 for dyestuff impurities and 4.0 for chemical impurities.

Other Considerations

No single set of water quality criteria can apply to all wet finishing processes. The criteria that determine minimum water quality requirements for a specific process include: process type (desize, bleach, dye, finish); process temperature; dye class and fiber type; shade depth (pastel, medium or dark); batch or continuous process equipment; and process chemicals used.

Process water reuse in many mills requires a thorough analysis of the chemicals and mechanics of the wet finishing operations. Specifically, a mill should do the following:

- Survey wastewater strength and volume to identify process effluents most suitable for recycling. Some effluents, such as dyebaths containing poor-exhaust dyes, may be difficult to treat for recycling but may represent a small percentage of total wastewater volume.
- Determine the mineral water quality requirement for each process. An understanding of the process chemistry is essential. In most cases, bench or pilot scale reuse tests are required.
- Determine if any process or process cycles must be excluded from the recycle system. It may be necessary to use fresh makeup water in the critical processes and use recycled water in other processes.
- Consider the separate treatment or recycling of wastewater from specific unit processes versus the treatment and recycling of the composite plant effluent. In most cases, the recycling of unit process effluents offers a better opportunity and minimizes the chance of incompatible chemicals.
- Review the treatment technologies available for reuse to select the best one suited for a particular situation.

Equipment Alternatives

Biological treatment reduces soluble organics and other contaminants in wastewater that are not removed in primary treatment.

In an activated sludge process, wastewater contacts microorganisms under aeration. The aeration provides needed dissolved oxygen for biological degradation of organics. Different microbes will assimilate different contaminants. Filtration is used to remove suspended solids and turbidity. Color also can be removed successfully if the color is treated chemically and precipitated prior to the filter.

Lime-soda softening is used to remove hardness and alkalinity from wastewater. In some cases, silica also is removed. Hardness and alkalinity are removed by conversion to insoluble precipitates. The precipitates are separated by means of settling and filtration. Ultrafiltration reduces turbidity, colloidal particles (such as silica) and some dissolved solids.

Ultrafiltration is a low-pressure (50 to 100 psi) membrane process that separates suspended solids and high molecular-weight dissolved solids.The separation is performed by a semi-permeable membrane. Low-molecular-weight dissolved solids (salts, surfactants) pass through the membrane and are discharged with the permeate. High-molecular-weight dissolved solids (>3,000 units), colloids and suspended solids are concentrated and rejected.

The process fluid flows across the membrane at high velocity to prevent "caking" buildup. As with reverse osmosis, two streams are produced: a reject (or concentrate) stream and a clean stream.

Activated carbon adsorption removes organics, color and chlorine. A filter vessel containing a highly porous activated carbon media with high surface area adsorbs organics or removes trace amounts of chlorine from a water stream. The carbon media must be replaced periodically or heat-regenerated after exhaustion. Higher loadings require more regenerations.

Reverse osmosis removes dissolved solids from a water stream. A pressure differential drives fresh, clean permeate through a semi-permeable membrane (film composite or cellulose acetate). Salts are unable to pass through the membrane and remain in the concentrate. A typical reverse osmosis system recovers 75 percent of the permeate. A second stream contains the concentrated salts. Up to 99 percent of the dissolved solids are removed.

Demineralization removes cations and anions from water. The basic process is ion exchange. Cation and anion resins are used to exchange H+ and OH– (respectively) for ions in the inlet stream.

Although extremely pure water results, the ion exchange is rarely 100-percent complete. Small amounts of sodium will leak from the cation unit and not all of the silica will be removed in the anion unit.

Electrodialysis can be used to reduce or concentrate total dissolved solids in a water stream or a reduced osmosis reject concentrate. It uses direct electrical current applied in conjunction with cationic and anionic semi-permeable membranes. The current draws cationic species toward a negatively charged cathode and anionic species toward the positively charged anode. The ions pass through a selective membrane and are held back. A concentrate and a demineralized stream are produced.

Electrodialysis can achieve an 80-percent reduction in dissolved solids or a 20-percent reduction in feed stream volume.

Chemical treatment is used for water neutralization, oxidation/reduction and coagulation/flocculation. These functions are carried out in reaction tanks and vessels to allow for solids separation. Color and TSS can be removed or reduced with proprietary coagulants and flocculants.

Color removal and solids removal can take place in unit operations such as clarification, flotation and filtration, by using coagulants and flocculants.

Case History: Dyebath Water Reuse

A particular textile plant dyes and finishes carpet fabrics. The dyeing is done in six open Beck machines. The dye chemistry consists of acid or dispersed dyes.

Dyeing and at least one rinse cycle are done in the Beck machine. Also, stain-fast treatment is done at a pH of around 2.0 using sulfuric acid. Approximately 150,000 gallons of water per day are required for the dyeing operation.

The plant pays a total of $6.40 per 1,000 gallons for water and sewerage to the local municipal sewer authority. The discharge limitations are stringent and their treatment costs are high. The out fall of the waste treatment plant contributes approximately 80 percent of the total flow of a local trout stream.

Treatment Scheme

There is no established water criteria for use in dyeing carpet. In the treatment of the dyebath rinse water, only two important criteria are used to determine the effectiveness of a treatment program: no color and low turbidity.

The mill evaluated various treatment techniques, including dissolved air flotation and filtration. The filter disk was chosen as the preferred technique with a chemical treatment program as follows: pH adjustment to neutral followed by polymer feed at 100 ppm. All mixing is done in-line with a series of static mixers prior to the disk filter. An easily filtered floc is formed.

Color and suspended solids are removed by passing the treated water through the filter disk and filtering out coagulated and flocculated particles. After a pre-set head pressure is reached, the filter is backwashed and the dewatered solids are removed for disposal. Excellent filtrate water quality is achieved with a significant reduction in color, turbidity and suspended solids.

The key to effective color and solids removal is the polymer treatment program. The polymer product, the end-result of an extensive research program, is a proprietary blend of coagulants designed specifically for cost-effective color removal. It performs at one-third the dosage of a previously used alum/polymer program with one-tenth the sludge volume.

Because the dye machine construction is of 304 stainless steel and operates at more than 240°F, it is important to keep chloride concentration below 100 ppm to avoid stress cracking. Even after seven cycles, chlorides were well below 100 ppm. The chemical treatment program was chosen with this target in mind. After filter disk treatment, water is recycled for use both as boiler water makeup and dye batch makeup. Live steam injection is used in the dye Becks, which offers a considerable amount of dilution. Approximately 19,000 gallons per day are used as boiler makeup and the rest is used as makeup for the dyebath (Figure 1).

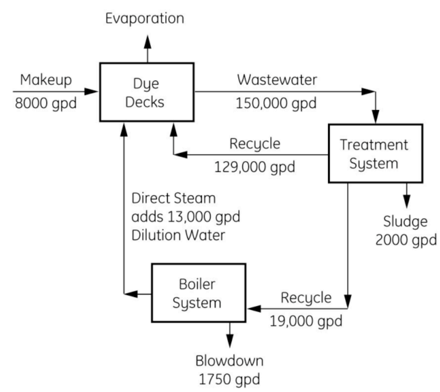

Figure 1: Carpet Mill Approximate Water Balance After Recycling

Cost Reduction

A capital investment of approximately $180,000 was needed to implement the new filter disk operation. Water and sewerage costs were averaging $960 per day prior to the new installation.

Costs for chemical treatment and filter disk operation now average $300 per day. The net savings gained from reusing water amounts to more than $600 per day. In addition, there have been no penalties based on high suspended solids discharge, and the environmental impact of the program is of great benefit to the local authority. The capital investment was paid off in less than one year.

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