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# A NOVEL GREEN TREATMENT FOR TEXTILES INDUSTRY AS A SUSTAINABLE TECHNOLOGY

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**Abstract :** Sustainability is rapidly moving from the wings to center stage. Overconsumption of non-renewable and renewable resources, as well as the concomitant production of waste has brought the world to a crossroads. Green chemistry, along with other green sciences technologies, must play a leading role in bringing about a sustainable society. The Sustainability: Contributions through Science and Technology series focuses on the role science can play in developing technologies that lessen our environmental impact. This highly interdisciplinary series discusses significant and timely topics ranging from energy research to the implementation of sustainable technologies. Our intention is for scientists from a variety of disciplines to provide contributions that recognize how the development of green technologies affects the triple bottom line (society, economic, and environment). The series will be of interest to academics, researchers, professionals, business leaders, policy makers, and students, as well as individuals who want to know the basics of the science and technology of sustainability.

.**Keywords:**

## INTRODUCTION

'Sustainable', 'greener' and 'cleaner' production has recently become important issues in textile manufacturing processes. The supply chain of textiles includes fibre production, yarn spinning, fabric manufacturing, textile wet processing, final products distribution (retailing, marketing and merchandising) and disposal. Among the different steps in the supply chain, the textile wet processing involves the use of large amounts of energy, chemicals and water, etc. Thus, the industry is now seeking solutions to achieve 'sustainable', 'greener' and 'cleaner' production methods in its daily operations.

### 1.1 TWELVE PRINCIPLES OF GREEN CHEMISTRY FOR TEXTILE WET PROCESSING

What is textile wet processing (1)? After textile materials have been made, by being spun into yarn or woven into fabric, they still contain impurities which make them undesirable for immediate use. Such textiles are usually referred to as 'grey textiles' or 'grey goods'-they are unattractive to consumers because of their appearance, handle (feel), and lack of serviceability and durability. Textile wet processing is the collective term for the processes that are used to improve the textiles in terms of these properties. The most common way to examine textile wet processing is to split it into the following three stages:

1. Pretreatment or preparation
2. Colouration (dyeing and printing)
3. Finishing

The pretreatment consists of a series of chemical and other treatments which are applied to textiles at the grey stage. At this stage, the textiles cannot be dyed or printed. The pretreatment processes improve the textiles so that they are able to accept dyes and chemicals in the later stages of textile wet processing. Colouration includes dyeing which adds colour to the textiles, which would otherwise be white only, and printing which provides special design to suit consumer requirements. Without the colouration process, there would be no place for textile designers (Leung, Lo, and Yeung 1996). In addition, the consumer also expects textiles to fulfil certain end-use requirements. For example, a raincoat should at least be

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waterproofed, and a woollen sweater should be mothproofed. In order to meet such expectations, textiles must undergo various finishing processes. These consist of mechanical and/or chemical treatment, and take place after colouration and before the material is made up into a garment. Moreover, in the textile wet processing, various chemicals and chemical reactions are involved and have been applied to the textile materials. If the chemicals such as dyes are not all picked up by the fibres or the chemical reactions are not fully completed, a residual amount of chemicals will be discharged. Although the amount of chemicals can be estimated and eliminated, there is still a risk of having a harmful effect on the environment.

The concept of green chemistry can provide a solution to achieve 'sustainable', 'greener' and 'cleaner' production in textile wet processing.

## IMPORTANCE OF GREEN CHEMISTRY IN TEXTILE WET PROCESSING

Basic concept of green chemistry can help us to modify textile wet processing in greener, cleaner and more sustainable ways.

### 1.2.1 Pretreatment Process

The aim of pretreatment processes in textile wet processing is to treat the goods by standard procedures so that they are brought to a state where they can be dyed, printed or finished without showing any fault or damage on the material. The pretreated textile materials should have the following properties:

1. Uniform power of absorption for dyes and chemicals in subsequent processes
2. An even water imbibitions value
3. Removal of all types of impurities, including broken seed
4. Absence of creases and wrinkles
5. High whiteness value

The pretreatment process is a non-added-value stage of the colouration process, and for this reason, the pretreatment stage of the process is often not optimized. Frequently, the pretreatment process is excessive, and high quantities of chemicals, auxiliaries and utilities such as water, steam, electricity and time are unnecessarily consumed. This can result in a high carryover of pretreatment residues (cotton impurities and pretreatment auxiliaries) that will have a negative influence on subsequent colouration processes and will require long multi-stage intermediate wash-off procedures which will consequently harm the environment. Therefore, the pretreatment process must balance the requirements of the colouration and finishing stages and the intended end uses of the textile material with the optimised use of chemicals and chemical reaction.

### 1.2.2 Colouration Process

Colouration in board refers to dyeing and printing. The objective of dyeing is the uniform colouration of the textile materials, usually to match a pre-specified colour. Any significant difference in colour from that requested by the customer, and any variation in the levelness of the colour of a fabric will be immediately apparent. Dyeing of a textile material can be achieved in a number of different ways (2):

1. Direct dyeing, in which the dye in the aqueous solution in contact with the material is gradually absorbed into the fibres because of the inherent substantively
2. Dyeing with a soluble precursor of the dye, which forms an insoluble pigment deep within the fibres upon treatment after dyeing
3. Direct dyeing followed by chemical reaction of the dye with appropriate groups in the fibre
4. Adhesion of dye or pigment to the surface of the fibres using an appropriate binder

All of these methods require that the fibres, at some stage, absorb the dye, or an appropriate precursor, from an aqueous solution. This process is essentially reversible. However, the precipitation of a pigment and reaction with the fibre are irreversible chemical processes. The discharge of pollution from dyeing processes occurs in two critical ways (3):

1. When dye is applied to the fabric, the colouring agent, such as dye, is not completely taken up by the textile materials.
2. There are inevitably some residual amounts of dyes that cannot be absorbed, and although efforts are currently made to recycle them, there are large quantities that cannot be used, either because the particular shade is no longer applicable for the next dyeing process, or because the dilution is too great to make recovery economically possible.

Like dyeing, printing is a type of colouration process, but it is a 'localised' colouration in which only a desired portion of the textile material, normally fabric, is being coloured. Printing is usually achieved by applying thickened pastes containing dyes or pigments onto a fabric surface according to the given colour design. In textile printing, the printing paste that is being used contains a thick substance such as starch, gum or resin that greatly increases the viscosity of the colouring agent applied. However, if an excessive amount of printing paste is used and discarded after the printing process, subsequent water pollution problems will be created. In order to reduce the risk of pollution, the printing paste often can be easily collected, with a lesser amount lost but that is also easily absorbed by the fibre. In textile printing, the printing paste is forced to colour the fabric; if the absorption of the printing paste can be increased by applying additional force, the wash-out process after printing can be minimised, thereby leading to a lower amount of discarded pollutants.

### 1.2.3 Finishing Process

The general aim of textile finishing is to improve the attractiveness and/or serviceability of the textile material, mostly in fabric form. There are many finishing processes, each producing a different effect, but they all share five specific objectives of finishing (4):

1. Improve the dimensional stability of the fabric, e.g., by stentering, compressive shrinkage and heat setting
2. Modify the handle of the fabric, e.g., by softening, stiffening and resin finishing
3. Improve the appearance of the fabric, e.g., by calendaring and pressing
4. Modify the serviceability of the fabric, e.g., by waterproofing and flame retardation
5. Improve the durability of the fabric, e.g., by mothproofing and mildew proofing

Although all fabrics do not need to undergo the same finishing processes, different types of chemicals and chemical reactions would be involved in achieving the final effect. The chemicals used in various finishing processes may be harmful when discharged into the wastewater stream, and the presence of treatment chemicals in the finished products can cause skin reactions in some people. Disposal of finished products after prolonged use will allow leaching of any residual finish to take place, with further harm resulting once it reaches the groundwater.

## WATER REQUIREMENT FOR TEXTILE WET PROCESSING

In textile wet processing, water consumption is far greater than the amounts of fibres processed. It is the ubiquitous solvent for the solutions of chemicals used. Rinsing and washing operations alone consume enormous amounts of water. Steam is still the major heat-transfer medium for many processes, and the quality of water fed to boilers is often critical (5).

Water for textile wet processing may come from a variety of sources. These include surface water from rivers and lakes as well as subterranean water from wells. The water may be obtained directly from the source or from the local municipality. Natural and pretreated water may contain a variety of chemical species that can influence textile wet processing. Different kinds of salts may be in the water, depending on the geological formations through which the water has flowed. These salts are mainly the carbonates (CO32?), hydrocarbonates (HCO3? more commonly named bicarbonates), sulphates (SO42?) and chlorides (Cl?) of calcium (Ca2+), magnesium (Mg2+) and sodium (Na+). Other than dissolved salts of natural origins, water may also contain a variety of other salts from human or industrial activities. These include nitrates (NO3?), phosphates (HPO42? and H2PO4?) and various kinds of metal ions. The ions of certain transition metals such as iron, copper and manganese can be easily found. The typical quality of water for textile wet processing is shown in Table 1.1 (6).

After textile wet processing, a large quantity of effluent water will be discharged into public sewerage systems or as surface water on open land, where it is treated until it achieves a given tolerance limit. The characteristics of effluent water vary widely among various textile wet-processing methods, and the overall estimated range is pH value (6.7-9.5); total alkalinity (500-796 ppm); total dissolved substances (2180-3600 ppm); suspended solids (80-720 ppm); biological oxygen demand (60-540 ppm); chemical oxygen demand (592-800 ppm); Chlorides (as Cl?) (488-1390 ppm); sulphate (SO42?) (47-500 ppm); calcium (Ca2+) (8-76 ppm); magnesium (Mg2+) and sodium (as Na+) (610-2175 ppm).

## SUSTAINABILITY CONSIDERATION OF CONVENTIONAL TEXTILE WET PROCESSING

For sustainable development in textile wet processing industry is now evaluating the following considerations.

### 1.4.1 Accurate Colour Communication

A dyer is required to match the colour of the client's 'standard' or reference shade on a particular quality of fabric and with the equipment available in the factory. The target may be electronic, in the form of reflectance data, or it may be a physical sample of coloured material or a combination of both. In the case of a physical target shade, this usually requires the dyer to match the 'standard' under several light sources to produce a nonmetameric match. In order to avoid gross changes of colour, the colour standard should be as colour constant as possible under different illuminants (7).

Achieving a particular colour typically involves a mixture of three dyes, or trichromatic, of yellow, red and blue. A dyer will often have a preferred set of primaries that have good dyeing behaviour and from which the widest range of shades can be economically achieved, along with additional dyes for specific requirements of shade, fastness or mesmerism.

### 1.4.2 Intelligent Dye Selection for Product Durability

Fastness is the resistance of a dyed textile to colour removal or modification of shade under the action of a range of agencies, including light, water, washing, perspiration, environmental contaminants, physical abrasion, etc. Standard test methods for assessing the fastness of dyed textiles are available from the International Organisation for Standardisation (ISO) or from the American Association of Textile Chemists and Colorists (AATCC). Meeting the fastness requirements of the customer is mainly achieved by:

1. Intelligent dye selection
2. Efficient washing-off processes in which loose or unfixed dye is removed from the fibre after dyeing.

### 1.4.3 Intelligent Dye Selection for Chemical Compliance

Factories producing fabrics use a wide range of chemicals, some of which have the potential to harm workers and cause irreversible damage if allowed to enter the environment untreated. Small quantities (residues) of some harmful chemicals on clothing can also pose a risk to consumers and reputational damage for the retailer or brand. Most responsible dye manufacturers abandoned the production of carcinogenic benzidine dyes many years ago in the light of evidence of increased levels of bladder cancer among their own workers. However, many of these dyes are still available today in major textile manufacturing locations. In situations where there is little or no regard for health and safety in the workplace, this can have tragic consequences for those involved in handling these chemicals.

### 1.4.4 Intelligent Process Selection for Improved Resource Efficiency

Freshwater is an increasingly scarce resource as the demands of an ever-growing world population and the agricultural activity needed to support it consume a steadily rising proportion of global freshwater resources. The textile industry generally needs to find ways to reduce its water consumption, and as a major user, and potential polluter, of water, the textile wet-processing industry is under particular pressure to reduce water consumption on both envi-ronmental and economic grounds. Securing a reliable and economic supply of water is now a strategic imperative for textile operation.

We have therefore witnessed a recent upsurge of interest in the so-called 'water footprint' of products, in particular cotton textiles with their associated issues of irrigation and pesticide use (8). The preparation, colouration and finishing stages of fabric manufacture are significant contributors to the overall water footprint of textiles and clothing, and so there is a renewed interest in optimised water use and investigation of the possibilities of water re-use in dyeing.

As so many textile processing steps require the use of hot water, minimizing the water consumption per unit of production also has a concomitant benefit in energy consumption. Given the levels of public and corporate concern about global warming and climate change, the textile industry cannot afford to ignore the pressure to reduce the amount of energy embedded in its products-in other words, to reduce their 'carbon footprint'. The following measures for water and energy management are identified:

- Monitor water and energy consumption in the various processes
- Install flow-control devices and automatic stop valves on continuous machinery
- Install automatic controllers for control of fill volume

and liquor temperature in batch wise dyeing machinery

- Establish standard operating procedures in order to avoid wastage of resources
- Optimise production scheduling
- Investigate possibilities for combining process steps, e.g., scour/dye, dye/finish
- Install low-liquor-ratio machinery for batch processing
- Install low add-on equipment for continuous application
- Improve washing efficiency in batch and continuous processing
- Re-use cooling water as process water
- Install heat-recovery systems to win back thermal energy from dropped dye baths and wash baths.

The importance of right-first-time dyeing to minimize waste during the dyeing process has long been emphasized by leading dye manufacturers, and much of their innovation in terms of both new dyes and new application processes over the past 20 years has been directed towards reducing the demand for both water and energy.

### 1.4.5 Waste Minimization and Pollution Control

Basically there are two approaches to reducing pollution arising from the textile wet-processing sector:

1. Effluent treatment or end-of-pipe solutions
2. Waste minimisation or source-reduction solutions

The Controlled Colouration concept describes textile colouration processes carried out in a way that minimizes the impact on the environment. by The controls that the dyestuff manu-facturer can exert are:

- Control of dyeing behavior
- Control of product quality
- Control of application processes
- Control of environmental impact

For example, some of the factors that must be taken into account when designing reactive dyes for reduced environmental impact are:

1) Careful choice of intermediates: no banned amines, minimum adsorbable organic halogen
2) High colour yield: high-fixation, multifunctional dyes leading to reduced levels of colour in effluent
3) Suitability for ultra-low liquor ratio dyeing machinery: to minimize energy, water and chemicals consumption
4) Right-first-time dyeing through dyestuff compatibility: to minimize wasteful shading additions or reprocessing

The environmental problems facing the textile wet-processing industry cannot be solved using outdated products, processes or machinery. Innovation is required to address the environmental issues facing the supply chain, and dyestuff manufacturers have a key role to play. As well as product innovation, the other major contribution that the innovative dyestuff company can make to cleaner textile production is application process innovation. This combination of novel dyestuffs and optimised application processes leads to:

- Minimised resource consumption for lower environmental impact
- Maximised productivity by achieving higher throughput from available assets

Well-accepted general principles for wastewater management and treatment include (9):

- Characterisation of the different waste streams arising from the processes carried out
- Segregation of effluents at source according to their contaminant load and type
- Allocating contaminated wastewater streams to the most appropriate treatment
- Avoiding the introduction of wastewater components into biological treatment systems that could cause the system to malfunction
- Treating waste streams containing a relevant non-biological fraction by appropriate techniques before, or instead of, final biological treatment

## DEVELOPMENT OF NON-AQUEOUS GREEN TREATMENT

Growing demands regarding the environmental friendliness of finishing processes as well as the functionality of textiles have increased the interest in physically induced techniques for surface modification and coating of textiles. In general, after the application of water-based finishing systems, the textile needs to be dried. The removal of water is energy intensive and therefore environmentally harmful and expensive. Therefore, non-aqueous treatment should be a green solution to conventional textile wet processing (10).

Plasma treatment, being a dry process, represents an economical alternative. The main advantages of such plasma treatments are:

- The electrons in low-temperature plasmas are able to cleave covalent chemical bonds, thereby producing physical and chemical modifications of the surface of the treated substrate without changing the fibre properties.

- There is a minimal consumption of chemicals and no drying process is required.
- The processes have a high level of environmental compatibility.
- The processes can be applied to almost all kinds of fibres.

During plasma treatment, the textile stays dry and, accordingly, drying processes can be avoided, no wastewater is generated, and no (or less) chemicals are required. Further advantages of plasma technology include the extremely short treatment time and the low application temperature. Therefore, plasma treatment represents an energy-efficient and economic alternative to classical textile finishing processes. The following chapters discuss the application of plasma treatment as an alternative to different textile wet-processing methods (11).

## CONCLUSIONS

This chapter reviewed recent sustainable considerations of textile wet processing and introduced the concept of plasma treatment to replace conventional textile wet processing. The remaining chapters discuss the application of plasma treatment as an alternative to different methods of textile wet processing.

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