



HAL
open science

A Concise Theoretical Aspect of Reactive Dyeing and Solvent Dyeing

Saima Mahjabin

► **To cite this version:**

Saima Mahjabin. A Concise Theoretical Aspect of Reactive Dyeing and Solvent Dyeing. Journal of Fareast International University, 2023, 6 (1), pp.5-13. <hal-04542714>

HAL Id: hal-04542714

<https://hal.science/hal-04542714v1>

Submitted on 11 Apr 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons CC BY-NC 4.0 - Attribution - Non-commercial use - International License

A Concise Theoretical Aspect of Reactive Dyeing and Solvent Dyeing

Saima Mahjabin¹

Keywords: Reactive Dye, Cellulosic Fiber, Solvent Dyeing, Dyeing Bath, Environmental Ecology

Journal of Fareast International University [ISSN 2519-9951]

Volume 6, Issue 1, 2023 [Pages 5-13]

Reactive dyes are particularly popular for cellulosic fiber and clothes since they are ecologically friendly and have strong general fastness qualities as well. But the application of this sort of color needs a very high concentration of salt. The salt discharged from the dyeing bath raises salinity in the drain water stream, which significantly damages environmental ecology. This review describes how to reduce the use of chemicals during the dyeing of cotton items using reactive dyes to replace the procedure of solvent dyeing. Therefore, this dyeing procedure might be a potential option for cleaner cotton manufacturing.

INTRODUCTION

Being a readily available and affordable material, cotton possesses a mix of evident properties, such as exceptional softness, sufficient warmth, high breathability, and decent comfort. Naturally, it is extensively employed in the garment sector, as well as in decorative and industrial applications (Yang, 2019). Reactive dyes are commonly used for dyeing cotton, principally because of their excellent colorfastness, dazzling color, broad color spectrum (Shu et al., 2018), and convenience of usage (Bhate et al., 2017). However, there are many disadvantages in the conventional reactive dyeing processes, for example, consuming vast amounts of water (generally 12–15 tons of water per ton of cotton fiber) (Xie et al., 2011) and discharging plenty of colored effluents with high salinity (Khatri et al., 2015) causing serious environmental pollution (Zheng, 2017). Furthermore, typical dyeing with reactive dyes entails extended dyeing periods and high dyeing temperatures (Burkinshaw & Kabambe, 2011). These difficulties affect the restricted use of reactive dyeing of cotton. Therefore, attempting to tackle these challenges, this paper discusses the theoretical features of reactive dyeing and solvent dyeing. Between the two of them, solvent dyeing is eco-friendly and creates less environmental contamination than reactive dye.

REACTIVE DYES

Reactive dyes are pigments that contain a reactive group. These pigments, which react with the textile substrate to form a homopolar connection, fall under the azo, anthraquinone, triphenodioxazine, or copper phthalocyanine chromophores categories. Cellulose is the most intriguing and essential type of fiber that has been commercially dyed with reactive dyes. The covalent connection for the formation of the dye molecules is the terminal -OH (hydroxyl) group of cellulosic fibers or the terminal amino (-NH₂) group of polyamide fibers. They have a significant impact on how cellulose fibers are colored and how impenetrable they are.

Properties of reactive dyes

Fibers made of cellulose protein polyamide are frequently colored using reactive dyes. Since the dyes are available in powder, fluid, and print paste forms, transportation is straightforward. Reactive dyes have a water-soluble chromophore group in their structure, which causes them to dissolve after dyeing. Covalent bonds are created between the dye and the fiber polymer, making them an indestructible part of the fiber. Covalent bonds are primarily formed between a terminal group of cellulosic fibers and a reactive group of

¹Lecturer, Department of Textile Engineering, Fareast International University, Dhaka, Bangladesh [saima.te@fiu.edu.bd]

reactive dyes. Additionally, reactive dyes are vulnerable to the harmful effects of UV light and have a relatively stable electron configuration. The dye exhibits excellent fastness properties, including good sweat fastness (rated at 4-5), good lightfastness (rated at about 6), brighter hues, and moderate rubbing fastness.

General Structure of reactive dyes

The chromophore group, the reactive system, a bridging group, and one or more solubilizing groups are the four key components of an extraordinarily water-soluble reactive dye molecule's conventional structure.

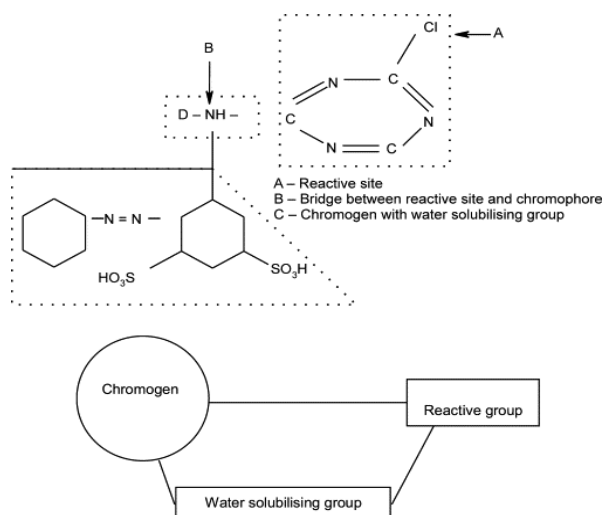


Figure 1: General Structure of a Reactive Dye

Chemistry of reactive dyes with cellulosic fibers

The dye can form a covalent bond with the -OH group of cellulosic fiber, the -NH₂, -OH, or -SH groups of protein fibers, or the -NH₂ group of polyamide, thanks to the reactive system. Based on the mechanism of the dye-fiber bond formation (nucleophile substitution and nucleophile addition) and the resilience of this connection to further processing (monofunctional, homo- or hetero-bifunctional, and polyfunctional), reactive systems can be divided into two groups.

Dyes react through Nucleophile substitution reactions

Di-chloro-triazinylamino dyes:

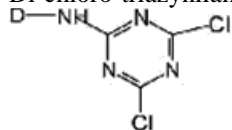


Figure 2: Di-chloro-triazinylamino dyes

Another name for this type of dye is cold reactive dye. These dyes require lower temperatures and kinder

alkalis for dyeing and fixing because they are more reactive than mono-chloro dyes.

Mono-chloro-triazinylamino dyes:

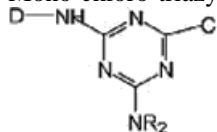


Figure 3: Mono-chloro-triazinylamino dyes

Reactive dyes from popular brands need to be fixed and dyed at higher temperatures and with stronger alkalis.

Mono-fluoro-triazinylamino dyes:

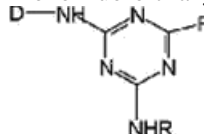


Figure 4: Mono-fluoro-triazinylamino dyes

Stronger alkali and a medium temperature are needed for dyeing and fixing Di-chloro-triazinylamino and Mono-chloro-triazinylamino kinds. These reactive dyes are popular brand names.

Dyes react through Nucleophilic addition reactions

Dyes containing Vinyl sulphone group:

These dyes are offered for sale in their soluble form, including RSO₂-CH₂-CH₂OSO₃Na and other derivatives of -hydroxy ethylene sulphonic acid. This is because they cannot dissolve in water.

Dyes containing Acrylamide group:

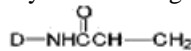


Figure 5: Acrylamide group

Compared to the vinyl sulphone type, the carbonyl group is less reactive and has a weaker ability to draw electrons.

α -chloro acrylamide dye:

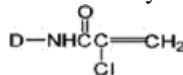


Figure 6: α -chloro acrylamide dye

They are more reactive than acrylamide dyes as they contain chlorine atoms (Iqbal et al., 2012).

Mechanism of reactive dyeing with cellulosic fibers

The dyeing procedure is completed in four steps: dye adsorption on the fiber surface, dye diffusion/exhaustion into the fiber interior, dye fixation in the fiber, and wash-off.

Adsorption of dye on the fiber surface: Adsorption describes the progression of color from the arrangement stage to the fiber stage, at the fiber stage, and the fiber surface. Fundamentally, reactive dyes and cellulose fibers have a negative charge when they enter the dye bath and repel one another, decreasing the substantiveness of the dye. Reducing the potential difference between the zeta between the fiber stage and the dye particle when salt is added to the dye bath lowers the negative charge, which increases absorption. Truthfully, salt serves as a depletion operator, aiding in the formation of color particles from the dye solution onto the surface of the fibers. The rate of adsorption is influenced by the amount of dye present, the amount of salt present, and the amount of alcohol present in the dye bath.

Diffusion/exhaustion of dyes into the interior of fiber:

Dye diffusion is the process by which dye molecules move from the fiber surface to the interior of the fiber. The temperature of the solution and the anticipated size of the dye molecules both affect how quickly dye molecules diffuse. The greater the temperature, the faster dye molecules of smaller sizes diffuse (Chen et al., 2015).

Fixation of dyes in the fiber: Fixation of dye is the process by which a reactive dye group interacts with the terminal -OH or -NH₂ group of the fiber to form a solid covalent bond. Since reactive dye fixation takes place in an alkaline environment, this crucial stage is controlled by introducing alkali to maintain the ideal pH. The establishment of a stable covalent bond between the dye molecules and the cellulose polymer is what gives reactive dyeing on cellulose fibers its resistance to washing. Substitution reactions with a heterocyclic ring of triazine dyes and addition reactions with vinyl sulphone dyes create the covalent bond between the dye and the cellulose fiber. Both colors are hydrolyzed, though, when they interact with water.

Wash off: This step is necessary for consistent coloring and high wash ability. To remove unfixed and hydrolyzed colors, as well as any lingering salt and alkali from the surface, the material needs to be thoroughly washed after dyeing. According to the requirements and shade, hot, cold, and soaping washes are used.

Classification of reactive dyes

Based on Reactive Group: Reactive dyes are of two types

The three different halogens (typically chlorine) derivatives of heterocyclics that contain nitrogen are the triazine group, pyrimidine dyes, and quinoxaline dyes.

Activated vinyl compounds are most frequently found in the three forms of vinyl sulphone, vinyl acrylamide, and vinyl sulphonamide.

Based on Reactivity: Reactive dyes are categorized into three types

Higher Reactive Dyes: Step fixing is easy with these dyes and can take place in a less alkaline solution due to their high reactivity. The pH of the dye bath is maintained at 10-11 by adding NaHCO₃. Procion MX, Drimarene K, and Levafix E-A are a few examples.

Dyes with Moderate Reactivity: These dyes have a medium level of reactivity. The pH of the dye bath is kept at 11-12 by adding Na₂CO₃ (soda ash). Cibacron F and Remazol RR dyes are two examples.

Lower Reactive Dyes: Because the reactivity of these dyes is low, they must be fixed with the substrate in a very alkaline environment. The pH of the dye bath is kept at 12-12.5 by combining a strong alkali, such as Na₂CO₃ (soda ash), with NaOH (Caustic soda). Procion H, Levafix E, Drimarene X, Basilan, and Cibacron are a few examples.

Based on Dyeing temperature and methods

Cold Brand: These dyes have a highly reactive group as a component, which makes them very reactive. These dyes can, therefore, be colored at lower temperatures, like 30 to 40 C. Several examples include Portion MX, Drimarene K, and Levafix E-A. The cold brand is dyed at a lower temperature than the medium brand. These dyes have a reactive group with a moderate level of reactivity. 40 to 60 degrees Celsius are the typical temperatures in this area. Among them are the dyes Remazol RR and Cibacron F.

Hot brand: Because these dyes contain the least reactive groups, a high temperature, such as 60–90 C, is required for dyeing. A few examples include Procion H, Levafix E, Drimarene X, and BasilanCibacron.

Based on controlling parameters (Recent classification)

Reactive dyes that can be controlled by alkali: This type of reactive dye fixes best at temperatures between 400 and 600 degrees Celsius. The neutral salt solution becomes considerably less fatigued before the addition of alkali. Due to its high reactivity, careful consideration should be given when adding alkali to achieve level coloring. Examples of reactive dyes include vinylsulphone,

dichloroquinoxaline, chlorodifluoropyrimidine, and dichlorotriazine.

Reactive dyes that are salt-controllable: The ideal fixing temperature for this type of reactive dye is between 80°C and 100°C. There is mildly noticeable exhaustion at neutral pH. The correct care should be taken when dosing salt to ensure that the amount of dyeing is due to the salt's low reactivity. Electrolyte addition should be done gradually. A few examples include trichloropyrimidine, aminochlorotriazine, aminochlorotriazineorbis, and aminofluorotriazine.

Temperature-controllable reactive dyes: In this dyeing process, the bond between the dye and the fiber is formed without the use of alkali and at temperatures ranging from 80°C to 100°C. No dye bath auxiliaries are required for level dyeing because this process is self-leveling. Controlling the temperature is necessary to get good results when dyeing. For instance, the drug Kayacelon reacts with bis (amino nicotinotriazine) (KYK).

Reactive groups present in reactive dye

Monochlorotriazine: This reactive dye is modest in reactivity and substantivity. These dyes require more demanding conditions for cellulosic material fixation because of their poor reactivity. To make these colors water soluble, pour 80-85 °C hot water over the powder and thoroughly mix it. Monochloromonohydroxy-s-triazine colors can effectively bond to wool when used in conditions that are moderately acidic because the keto form of the hydroxy-s-triazine ring predominates in these conditions.

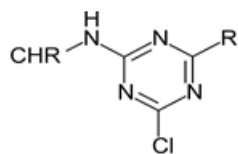


Figure 7: Monochlorotriazine reactive group

Dichlorotriazine: This dye is very reactive and may be easily attached to cellulosic fabrics, either by pad-batch dyeing at room temperature or batch-wise dyeing at 30-40°C. This means that to ensure adequate dye mobility on the fiber during the fatigue stage, small chromogens are preferred. This need makes these dyes ideal for brilliant dyeing but less appropriate for deep tertiary colors since the larger-size chromogens employed for this purpose sometimes fail to provide sufficient performance under low-temperature conditions. Some dichlorotriazine dyes have a flaw in that, at low pH levels, the dyed fiber bond is broken by acid-

catalyzed hydrolysis, leading to deficiencies in fastness to washing or acid/alkaline perspiration. This flaw is most noticeable in red dyes with H acid as a coupling component, such as CI Reactive Red 1. When the dye undergoes partial hydrolysis to generate the 2-chloro-4-hydroxy-s-triazinylamino species, it loses the opportunity to accomplish fixing with the remaining chlorine atom. Under the alkaline conditions of the fixation step, ionization of the acidic 4-hydroxy substituent generates a significant feedback of negativity into the triazine ring, which completely deactivates the remaining 2-chloro substituent. The 2-amino-4-chloro- and 2-alkoxy-4-chloro-triazines are two additional groups of monofunctional dyes that are produced when dichlorotriazine dyes are controlled-reactive with amines or alcohols. The latter is less reactive than the parent dichlorotriazine types but more reactive than the former. The bulky isopropoxy group was chosen to disrupt the substituted triazine system's planarity, making it easier to wash off the unfixed dye from the printed fabric.

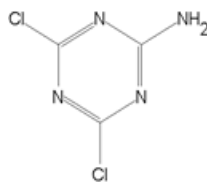


Figure 8: Dichlorotriazine reactive group

Vinyl Sulphone: Vinyl sulphone reactive dyes are dyes that include vinyl sulphone groups. Hoechst (Germany) initially sold the dye as Remalan Fast dyes for wool and then as Remazol reactive dyes for cellulose. The most common vinyl sulphone group utilized commercially is a b-sulfate residue, with a b-chloro residue appearing on occasion. Vinyl sulphone is the reactive group of vinyl sulphone-based reactive dyes. VS dyes are used in exhaust dyeing, cold pad batch processing, and automated batch-wise dyeing equipment. These are also utilized in one-phase or two-phase printing applications. The range provides excellent light and washes quickly. The discharge and resist printing process produces excellent white effects on colored grounds. It is very stable in both dry and neutral solutions. Under the right circumstances, they react chemically with dyes with the hydroxyl group of cellulose in the presence of alkali to form solid and covalent bonds that produce vibrant hues with excellent fastness properties. Vinyl Sulphone Base Dyes have a high water solubility and are ideal for both Exhaust/Pad-batch applications. Printing and dyeing using discharge, a low affinity for cellulosic fibers exists for VS dyestuff in the absence of salt and alkali. As a

result, they are appropriate for usage on the pad. The dyestuffs become more substantial when Glauber salt or regular salt and alkali are added, making them suitable for all conventional dyeing equipment for yarn in hanks, loose material, packages, and component items.

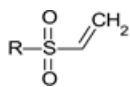


Figure 9: Vinyl sulphone reactive group

Bi-functional group: Most reactive dyes that have recently been created are bi-functional, having the same or distinct reactive groups in the dye molecule. Bi-functional dyes feature two reactive groups that are the same or different. They are well-known for their high dyeing efficiency and fastness. By carefully choosing the appropriate reactive groups and chromophores, bi-functional dyes with strong dyeing properties can be produced. It is simple to demonstrate that dyes with two similar reactive groups and dyes with two distinct reactive groups have a better fixation yield than dyes with just one reactive group. Bi-functional dyes with two comparable functional groups are known as homo bi-functional group dyes. Dyes with two separate functional groups are referred to as "hetero bi-functional group dyes." The dyes were of the common Dichlorotriazine type, with the end condensation of B-sulphate ethyl sulphone containing various kinds of reactive groups in a single molecule. Improved repeatability is offered by reactive dyes, especially for medium- to light-hued colors. Because of the triazine ring structure, they have excellent dyeing capabilities even for non-critical substrates. Because of the triazine ring structure, they have excellent dyeing capabilities even for non-critical substrates. Rarely are dyeing variables like temperature, heating rate, alkali dosage, and so forth going to affect this dye.

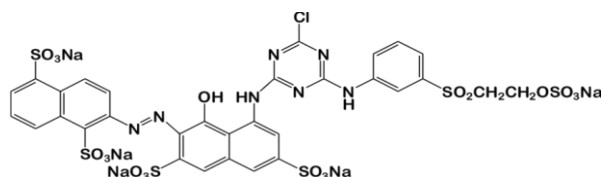


Figure 10: Example of reactive dye with bi-functional group

Major Problem of reactive dyeing on cotton fiber

Cellulosic fiber undergoes a competing hydrolysis process when reactively dyed under the proper alkaline conditions. There is a dyeing loss because the dye molecules stay in the wastewater as a result of the oxy-dye form being non-reactive and 25% of the dye

molecule remaining in the water. The addition of a molecule of water causes a molecule to be cleft into two halves, which is known as hydrolysis. The extra water molecule provides a hydrogen ion (H+) to one part of the parent molecule. The leftover hydroxyl group (OH) is collected by another group. To achieve the desired enhanced wash fastness of reactive dyeing, the unfixed or hydrolyzed reactive dye must be appropriately rinsed out after dyeing. At least half of the total cost of a reactive dyeing process must go toward the washing-off stages and the treatment of the waste produced. It is essential to acknowledge that this aspect of the process poses a significant barrier to reactive dyes achieving the level of success that was anticipated at the time of their development (Sahar et al., 2018).

Factors affecting the rate of Hydrolysis

Liquor Ratio: The liquor ratio must be set based on the dyeing amount. It is important to remember that hydrolysis is enhanced by a higher liquor ratio and vice versa.

Salt Concentration: Because salt neutralizes the surface negative of fiber, increasing the salt concentration reduces hydrolysis up to a point and vice versa.

PH: All available hydroxyl groups of cellulose are ionized at PH 10-11, hence raising pH will only induce hydrolysis.

Temperature: As the temperature rises, more hydrolysis occurs.

Dye Reactivity: If the reactive group of a reactive dye is more reactive, the rate of hydrolysis and fixation will rise.

Dye Substantivity: More substantial dye generates more hydrolysis while reducing substantivity to a bare minimum or eliminating it entirely eliminating the build-up issue during dyeing and significantly decreasing the color yield problem (dyeing) of the dye.

Time: The longer the dyeing time, the more hydrolysis occurs, and vice versa. Oxide (O-) and sulfide bridges are less stable in alkaline hydrolysis, according to the bridge type. However, more stable bridges slow down the reaction rate as well as the hydrolysis.

Hydrolysis & number of reactive groups in a reactive dye

During the dyeing of cellulose with a reactive dye, covalent bond formation between dye and fiber and hydrolysis reactions between fiber and water in the co-occur dye bath. The hydrolyzed product cannot take part in the dyeing process because the dye only has one reactive group. However, if the dye includes more than one reactive group, i.e., bifunctional reactive dye, it will contain additional groups for fixation. Additional reactive groups have the crucial advantage of possibly boosting

dye fixation. If the likelihood of fixation of each reactive group is, say, 60% and hydrolysis of the first reactive group does not change the physical or chemical characteristics of the dye, the chance of dye-fiber bond formation in a bi-functional dye is 84%. A multifunctional dye has a higher fixing potential than a reactive dye that is not multifunctional, even though all structural phases of a dye have an impact on its dyeing behavior (Liu, 2004).

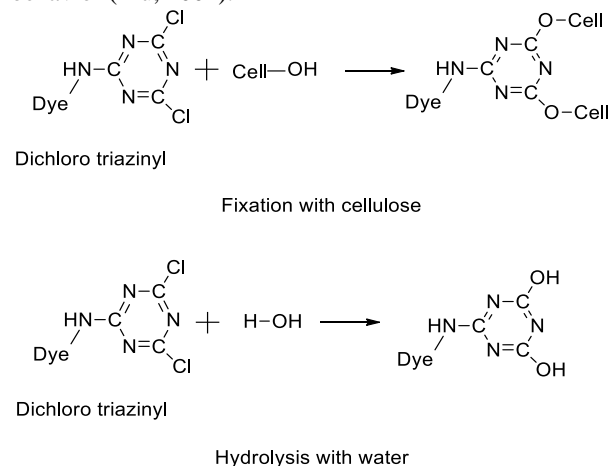


Figure 11: Hydrolysis of dichlorotriazine azo class of reactive dye

The figure shows that, instead of interacting with the cellulosic fiber's terminal group (-OH), the reactive group (dichlorotriazine) interacts with water and is hydrolyzed. As a consequence, dye is wasted. This dye loss is not only an economic loss, but it also harms our environment since these colorants are dumped with wastewater, which has a long life and may negatively impact the ecosystem.

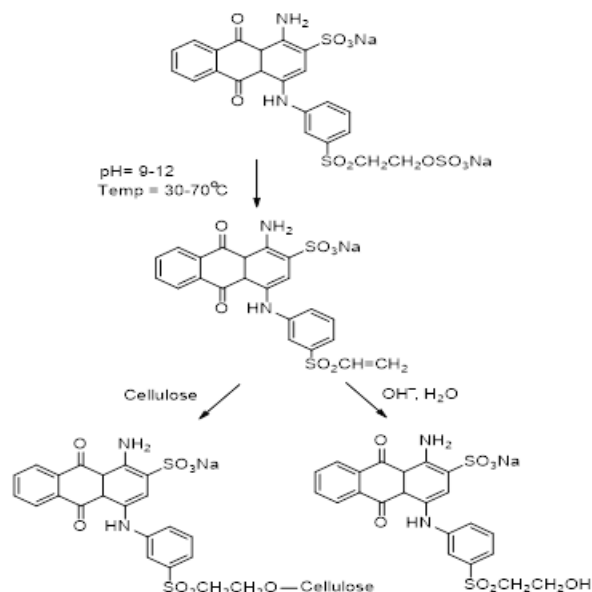


Figure 12: Hydrolysis of vinyl sulphone anthraquinone class of reactive dye

Potential problems due to hydrolysis of reactive dyes

- Hydrolysis decreases fixing, resulting in a significant loss of dye molecules. As a result, up to 40%-60% of dyes (on average 50%) are wasted in this scenario.
- In the exhaust dyeing technique, relatively large volumes of electrolyte are required; otherwise, dye hydrolysis will rise in the dye bath.
- It is critical to remove unreacted and hydrolyzed dye. The process is more time-consuming and complex than the dyeing stage itself, so it is only sometimes wholly satisfying.
- After dyeing, the cloth must be washed to remove unreacted and hydrolyzed dye, which may cost up to 50% of the overall dyeing cost.
- When the hydrolyzed dye is released as colored effluent, the cost of effluent increases. Additionally, many dyes are not biodegradable, and effluent treatment methods have difficulty removing color.
- Absorbable Organic Halides (AOX) may be at risk from hydrolyzed, unfixed halo heterocyclic reactive dyes.
- Because reactive dyes are hydrolyzed while covalently bonded to the substrate, fastness problems could result.
- Less storage space.
- A trailing issue for prolonged dyeing.
- Employing batch Shade operations.

SOLVENT DYEING

The wet processing of textiles has traditionally employed solvents for de-sizing, scouring, bleaching, mercerization, dyeing, and finishing. The use of solvents to expedite the dyeing process is one alternative method to save environmental expenses and restrict the production of effluent in the textile coloring business. Tetrachloroethylene, often referred to as perchloroethylene (PCE), trichloroethylene (TCE), and benzyl alcohol, are typical solvents that have been employed widely in recent years for solvent-assisted dyeing. The history of chlorinated solvent manufacturing and use is strongly tied to the growth and globalization of the synthetic and organic chemical industries. Solvent dyeing has a variety of disadvantages in addition to its advantages (Liu, 2004).

Applications of Solvent Dyeing

Dyeing of cellulosic fiber with nonaqueous reactive dye: Cotton was attempted to be dyed using reactive dye in a solution of dye/decamethyl Cyclopentasiloxane (D5). The sample was

submerged in soda ash solution, padded to get 140% pick-up, and then dyed in the dye/D5 suspension system to produce the best dyeing results. The technique included grinding the dye with oleic acid to acquire the best dyeing results. The fixing rate was 6% greater compared to a conventional water-based dyeing method, and the dye absorption in this system was above 99% without the need for electrolytes. The dyeing procedure also produced satisfactory color fastness, highlighting its potential as an innovative and creative method for water-conserving and salt-free solvent-assisted dyeing (Liu et al., 2012).

Silicone Waterless Dyeing of PET Fabric: With dispersion dye, the silicone waterless dyeing method exhibits effective dyeing capabilities. The employment of dispersants in this technique, however, may result in problems, including uneven dyeing, lifeless hues, and color blotches. This study investigates how dispersion dyeing is affected when poly naphthalene sulphonic acid dispersant sodium salt is added to the silicone waterless dyeing system. The fixing and level dyeing of disperse dye is impacted by the employment of dispersants and dyeing accelerants combined. Particle size and scanning electron microscopy investigations have shown that the production of dye aggregates on the fabric surface increases with the addition of additional dispersant. The findings show that the accelerant phase increases the dispersion of dispersed dyes and their aggregation, which causes a clustering of dyes and dispersants on the fabric surface and poor-level dyeing. As a result, dispersants cannot be used with accelerants in the silicone waterless dyeing technique, proving that commercial disperse dye is ineffective for use in this system to color polyester fabric (Li et al., 2011; Pei et al., 2022).

Dyeing of Nylon with D5 solvent: Decamethylcyclopentasiloxane (D5), a non-aqueous medium, was used in chemical fiber dyeing and washing due to a lack of water. A confocal laser scanning microscope (CLSM) and X-ray photoelectron spectroscopy (XPS) were used to examine the penetration of D5 into the interior of nylon fibers as well as its distribution throughout the fiber cross-section. By testing the solubility of pure disperse dye in D5, the viability of leaving the dispersing ingredient out of the dyeing formulation was examined. The solvent dyeing and washing technique for nylon was developed using pure dispersion colors in D5 solvent and nylon fabric. The results from CLSM and XPS spectra showed that D5 can diffuse into the surface of nylon fabric

with or without an accelerant, and the presence of the accelerant had no effect on D5's ability to penetrate and distribute equally throughout the fiber composition. The use of D5 as the dyeing medium led to an increase in K/S of 30% and 43% for azo and anthraquinone dyes, respectively, as compared to aqueous dyeing. In addition, the solvent may be recycled or recovered in amounts more than 99%. The ability to successfully dye using commercial dyes in a D5 solvent dyeing medium under standard dyeing conditions proves the viability of this dyeing method from a business standpoint (Saleem et al., 2020).

GES-assisted Solvent Dyeing of Silk: The research looked at how to dye silk using Acid Blue 281 and Acid Red 151 dyes while employing a glycerine-based eutectic solvent (GES) as a swelling agent. The GES, which was used to color silk, was created by mixing glycerine, urea, and chloride choline at room temperature. The dyeing variable research, including time, temperature, and GES concentration, was optimized using a statistical model (DOE). Acid Blue 281 and Acid Red 151 dyes were applied to silk fabric using the improved recipe, and the outcomes were contrasted with those of traditional aqueous silk dyeing. At 70°C for 35 minutes, with the assistance of GES, silk cloth is dyed with the specified color strength; this process is roughly 10 minutes faster than traditional aqueous silk dyeing. According to research on swelling, GES may be utilized to make silk cloth swell. Silk fabric dyed with GES had greater color strength than silk fabric treated conventionally as a result of its swelling tendency. Both traditional and GES-assisted solvent dyeing had good rubbing and lightfastness. Both traditional dyeing and GES-assisted solvent dyeing of silk produced equivalent results for washing fastness. In the solvent-assisted dyeing of silk fabric, this unique use of GES as a swelling agent may be a sustainable strategy (Pawar et al., 2021).

Dyeing of Wool with Solvents: In research, wool that had been pretreated with DMSO and dyed in non-aqueous green solvents was examined. Due to the needed alkaline post-treatment to match the fastness of mordant dyes, reactive dyeing of wool in deep colors might harm the wool keratin. According to the research, the colorfastness-integrity conundrum might be resolved by using organic solvents instead of water as the dyeing medium. The fundamental benefit of solvent dyeing is that it encourages covalent bonding, giving any hue outstanding colorfastness without the requirement for alkali treatment. Solvent

dyeing exhibited a covalent fixation average of 30% greater than aqueous dyeing, improving colorfastness at higher color depth ($\Delta K/S = 1.3-4.9$). The research found that pretreating wool with DMSO led to advantageous morphological and structural changes that improved its dyeability. These results are crucial for environmentally friendly wool dyeing and the phase-out of colors that include metals (Chen et al., 2016).

Disadvantages of Solvent Dyeing

- Solvents are costly, which raises manufacturing costs.
- Not all equipment is readily accessible.
- Existing dye molecules cannot be utilized in their entirety.
- A lot of organic solvents have the potential to cause bladder cancer in humans, as well as damage to the liver and kidneys (Wang A., 2020).

CONCLUSION

Solvent dyeing also has a lower evaporation temperature than water and consumes no fresh groundwater. Furthermore, the solvents may be virtually completely recovered using conventional recovery methods, which have more incredible benefits than reactive dye. Reactive dyeing necessitates the usage of new groundwater, while dye hydrolysis generates a significant quantity of waste dye and water. As a consequence, natural resources are running out. Due to its benefits, solvent dyeing may replace reactive dyeing.

Conflict of Interest

The author declares no conflicts of interest.

REFERENCES

- Bhate, P. M., Devi, R. V., Dugane, R., Hande, P. R., Shaikh, L., Vaidya, S., & Masand, S. (2017). A novel reactive dye system based on diazonium salts. *Dyes and Pigments: An International Journal*, 145, 208–215. <https://doi.org/10.1016/j.dyepig.2017.06.007>
- Burkinshaw, S. M., & Kabambe, O. (2011). Attempts to reduce water and chemical usage in the removal of bifunctional reactive dyes from cotton: Part 2 bis(vinyl sulfone), aminochlorotriazine/vinyl sulfone and bis(aminochlorotriazine/vinyl sulfone) dyes. *Dyes and Pigments: An International Journal*, 88(2), 220–229. <https://doi.org/10.1016/j.dyepig.2010.07.001>
- Chen, L., Wang, B., Chen, J., Ruan, X., & Yang, Y. (2016). Characterization of dimethyl sulfoxide-treated wool and enhancement of reactive wool dyeing in non-aqueous medium. *Textile Research Journal*, 86(5), 533–542. <https://doi.org/10.1177/0040517515591784>
- Chen, L., Wang, B., Ruan, X., Chen, J., & Yang, Y. (2015). Hydrolysis-free and fully recyclable reactive dyeing of cotton in green, non-nucleophilic solvents for a sustainable textile industry. *Journal of Cleaner Production*, 107, 550–556. <https://doi.org/10.1016/j.jclepro.2015.05.144>
- Iqbal, M., Khatri, Z., Ahmed, A., Mughal, J., & Ahmed, K. (2012). Prediction of low-sensitivity reactive dye recipe in exhaust dyeing influenced by material to liquor ratio and nature of salt. *Journal of Saudi Chemical Society*, 16(1), 1–6. <https://doi.org/10.1016/j.jscs.2010.10.015>
- Khatri, A., Peerzada, M. H., Mohsin, M., & White, M. (2015). A review on developments in dyeing cotton fabrics with reactive dyes for reducing effluent pollution. *Journal of Cleaner Production*, 87, 50–57. <https://doi.org/10.1016/j.jclepro.2014.09.017>
- Li, S. Z., Liu, J. Q., Li, Y. Q., & Li, L. M. (2011). Study on the dyeing of PET fiber with disperse dyes in D5 media. *Advanced Materials Research*, 331, 334–337. <https://doi.org/10.4028/www.scientific.net/amr.331.334>
- Liu, J., Ikushima, Y., & Shervani, Z. (2004). Investigation on the solubilization of organic dyes and micro-polarity in AOT water-in-CO₂ microemulsions with fluorinated co-surfactant by using UV-Vis spectroscopy. *The Journal of Supercritical Fluids*, 32(1–3), 97–103. <https://doi.org/10.1016/j.supflu.2004.02.006>
- Liu, J. Q., Miao, H. L., & Li, S. Z. (2012). Non-aqueous dyeing of reactive dyes in D5. *Advanced Materials Research*, 441, 138–144. <https://doi.org/10.4028/www.scientific.net/amr.441.138>
- Pawar, S. S., Madiwale, P. V., Pawar, A., & Adivarekar, R. V. (2021). Solvent assisted dyeing of silk fabric using glycerine based eutectic solvent as a swelling agent. *Research Journal of Textile and Apparel*, 25(1), 31–46. <https://doi.org/10.1108/rjta-01-2020-0007>
- Pei, L., Huang, Y., Zhang, H., & Wang, J. (2022). Effect of dispersant on disperse dyeing for polyester fabric in silicone waterless dyeing system. *Journal of the Textile Institute*, 113(2), 185–190. <https://doi.org/10.1080/00405000.2020.1868137>
- Sahar, A., Ali, S., Hussain, T., Irfan, M., Eliasson, B., & Iqbal, J. (2018). UV absorbers for cellulosic apparels: A computational and experimental study. *Spectrochimica Acta. Part A, Molecular and Biomolecular Spectroscopy*, 188, 355–361. <https://doi.org/10.1016/j.saa.2017.07.037>

- Saleem, M. A., Pei, L., Saleem, M. F., Shahid, S., & Wang, J. (2020). Sustainable dyeing of nylon with disperse dyes in Decamethylcyclopentasiloxane waterless dyeing system. *Journal of Cleaner Production*, 276(123258), 123258. <https://doi.org/10.1016/j.jclepro.2020.123258>
- Shu, D., Fang, K., Liu, X., Cai, Y., Zhang, X., & Zhang, J. (2018). Cleaner coloration of cotton fabric with reactive dyes using a pad-batch-steam dyeing process. *Journal of Cleaner Production*, 196, 935–942. <https://doi.org/10.1016/j.jclepro.2018.06.080>
- Xie, K., Cheng, F., Zhao, W., & Xu, L. (2011). Micelle dyeing with low liquor ratio for reactive dyes using dialkyl maleic acid ester surfactants. *Journal of Cleaner Production*, 19(4), 332–336. <https://doi.org/10.1016/j.jclepro.2010.10.006>
- Yang, L. (2019). Structure and properties of carboxymethyl cotton fabric loaded by reduced graphene oxide. *Carbohydrate Polymers*, 117–123.
- Zheng, H., Xu, Y., Zhang, J., Xiong, X., Yan, J., & Zheng, L. (2017). An ecofriendly dyeing of wool with supercritical carbon dioxide fluid. *Journal of Cleaner Production*, 143, 269–277. <https://doi.org/10.1016/j.jclepro.2016.12.115>

--0--