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A COMPREHENSIVE REVIEW ON REACTIVE DYE AND ITS CHEMICAL COMPONENTS

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ABSTRACT
Reactive dyes are the most popular class of synthetic dyes used in the dyeing and printing industries due to their wide range of shades, high fastness, and diversity in application. There are different kinds of reactive dyes that consist one or more unique reactive groups. This study covered some reactive dye components that react with cellulose to form a strong covalent bond and become an essential component of the fiber. In order to obtain the high wash-fastness characteristics, all unfixed dye is removed from the fiber's surface by the washing-off procedure. These dyes have completely different toxicological properties due to removal of the reactive group after dyeing and fixation. Thus, consumers using fabrics dyed with reactive dyes have not reported any instances of adverse reactions. Therefore, dyeing and printing with reactive dyes should always be the first alternative to increased value of product.

Keywords:
Reactive dye, Covalent bond, Cellulosic fiber, Dyeing, General Nature, Printing, Wash fastness.

I. Introduction
Currently, the textile industry is emerging as the primary organized sector in the country, contributing thirty percent of the overall revenues earned from exports. India has been producing printed textiles since the fourth century BC. Although color has always been an essential element, the art of dyeing and printing has contributed significantly to the aesthetic appeal of the textile world in all civilizations, from ancient times to the present [1]. Colors of the textile are the major point of attraction in any textiles. Various types of dyes are available to achieve the desired color. The textile industry ranked highest among all industries in the area of the application of dyes for the coloration of fiber [2].

In ancient times, natural dyes were the main source for dyeing textile materials. However, only natural dyes were insufficient to fulfill the required demand for dyed and printed textiles due to the limitations of natural dyes and the rising demand for these kinds of textiles. The natural dyes that were used in the early period have now been replaced by synthetic dyes in a wide range because these dyes are available in various colors and have good color fastness [3]. Today, almost every color available in the market is made with synthetic dyes, which are widely used in plenty of industries for printing and dyeing. The synthetic dyes can be named according to the chemical structure of their particular chromophoric group.

There are various types of dyes used in the textile industry, such as acid dyes, reactive dyes, basic dyes, azo dyes, direct dyes, vat dyes, and disperse dyes [4]. Dyes are classified as anionic, cationic, and non-ionic dyes. Acid dyes, reactive dyes, azo dyes, and direct dyes are anionic dyes, while basic dyes are cationic dyes [2]. Among all the dyes, reactive dyes are the most widely used class of synthetic dyes due to their wide shade, flexibility in application, and excellent fastness properties [5]. The natural and regenerated cellulose fibres, synthetic nylon, and natural protein fibres most readily coloured with reactive dyes [6].

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II. Reactive dyes

Reactive dyes for cellulose developed by Imperial Chemical Industry (ICI) in 1954. These dyes first appeared commercially in 1956 [7], as a low-cost method for providing cellulosic fibers an appropriate degree of color fastness. Due to their great fastness to wet treatment, these dyes are important. As the name of these dyes suggests, they chemically react with the fibre polymer. There are many types of reactive dyes which contain distinctive reactive group(s) i.e. with different reactive systems, that react with subtract to form a strong covalent bond and becomes an integral part of the fibre [8]. In cellulosic fibres, covalent bond is formed between the dye molecules and the terminal-OH (hydroxyl) group under alkaline pH conditions while in wool fibres or polyamide, covalent bond is formed between the dye molecules and the terminal -NH2 (amino) group under mildly acidic conditions [7].

The introduction of reactive dyes (Procion Yellow R., Brilliant Red 2B and Blue 3G) by ICI in 1956 is an important revolutionary in the history of synthetic dyes [7]. Usually, these three reactive dyes, red, yellow and blue, are used to mix to obtain novel color. Bright shades and excellent wash fastness properties are the trademark of reactive dyes [9-10]. It also covers a wide range of color spectrum and includes shades varying from bright to dark such as, Violet, Blue, Green, Red, Black, Yellow etc [11].

III. Components of reactive dyes

The general formula of reactive dyes containing reactive system depicted in **Figure 1** as: S-F-T-X. Here,

S- Solubilising groups (such as SO_3Na or COONa or combination of both) which impart solubility.

F- Chromophoric group usually an azo, metal-complex azo, anthraquinone, triphenyl dioxazines and formazan molecules or phthalocynanine residue. The chromophore is responsible for the colour, affinity and diffusion of dye. It is also called the chromogen or dye part (color producing part).

T- Bridging group which attach the reactive system X to the chromogen F. This group is usually -NH, -O-, -NHCO-, $-OCH_3-$, $-SO_3-$, etc.

X- Reactive system or group, which reacts chemically with the functional group of the fibre with the formation of covalent bond between the dye and the fibre.

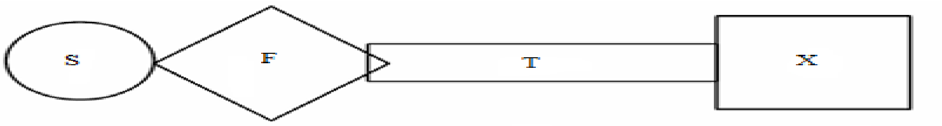

Figure 1. The general formula of reactive dyes [12]

An example of reactive dye with a dichlorotriazine group is C. I. Reactive Blue 109 shown in **Figure 2** [7, 11-12], an example of bifunctional reactive dye with a sulphatoethylsulphone group is Remazol Black B (CI Reactive Black 5) shown in **Figure 3** [15] and an example of trifunctional reactive dye is Remazol Red SBB (CI Reactive Red 181) shown in **Figure 4** [5].

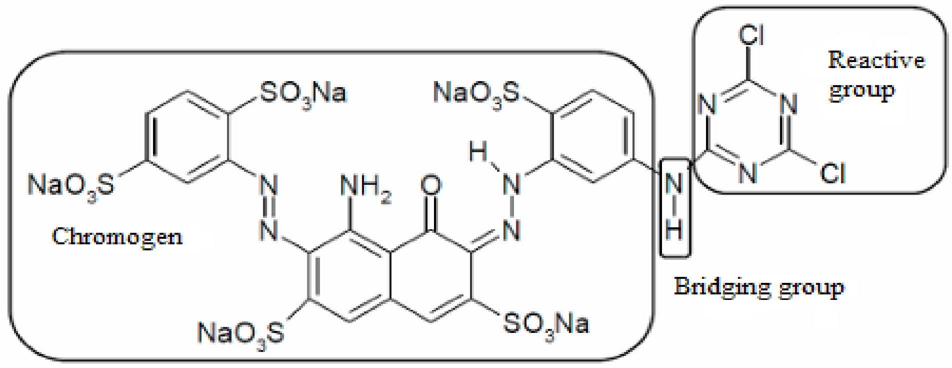

Figure 2. Molecular structure of a reactive dye- C.I. Reactive Blue 109 [12]

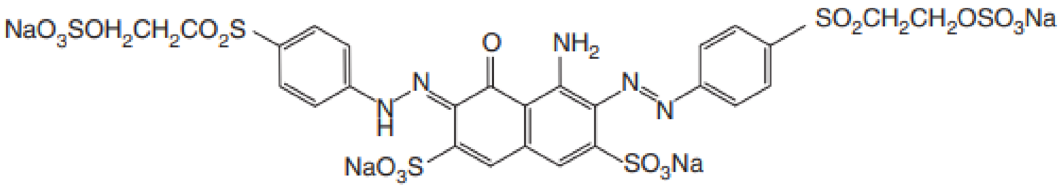

Figure 3. Molecular structure of a reactive dye- C.I. Reactive Black 5 [15]

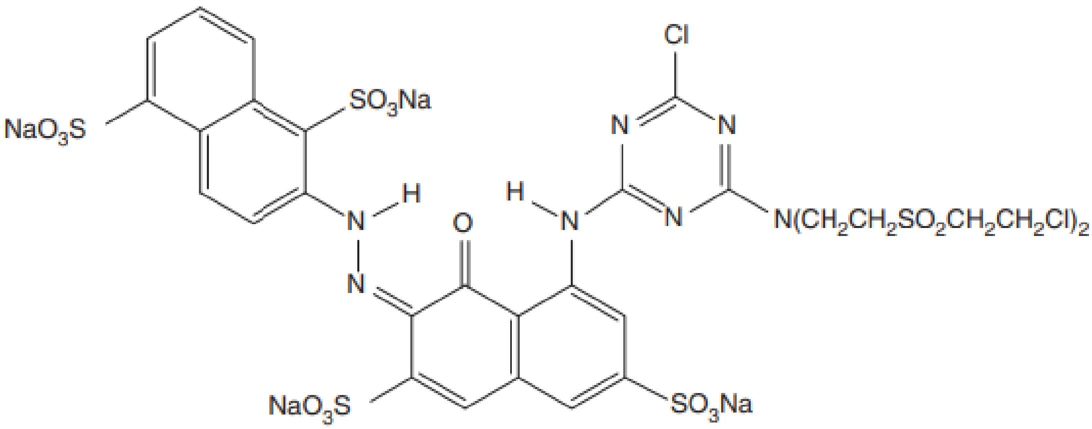

Figure 4. Molecular structure of a reactive dye- C.I. Reactive Red 181 [5]

IV. The General Nature of Reactive Dyes

Reactive dyeing essentially has two stages. In the first stage, dyes and dye derivatives that have been dissolved are first adsorbed at the fiber surfaces through hydrogen bonding and van der Waals interactions, after which they diffuse into the fibers from aqueous solutions with electrolyte (sodium sulfate or sodium chloride) until they are more or less evenly distributed throughout. Without electrolyte addition, adsorption of dye on the fiber will not occur [13]. High amounts of electrolytes, such as NaCl or Na_2SO_4 (30–100 g/L), are frequently utilized in the conventional dyeing process for cellulosic textiles using reactive dyes in order to inhibit negative charge build-up at the fiber surface and promote dye adsorption [14].

In the second stage, alkali is added to maintain a pH in the range of 11 in order to produce enough cellulosate anions (cell-O-) within the substrate to form a covalent bond between dye and fiber [13]. However, these alkaline conditions of aqueous produce hydroxyl ions. Because of these ions, more than 40% of the reactive dyes are able to form hydrolyzed dyes by reacting. This hydrolyzed dye has extreme affinity for the fiber due to hydrogen bonds and van der Waals interactions but is not able to make a covalent bond with fiber. After dyeing, washing off process is required for removal of hydrolyzed dye through washing and rinsing in order to achieve the high wash fastness properties [13,15-16].

V. Properties of reactive dyes

5.1 Light fastness

Textile materials dyed with reactive dyes offer excellent light fastness, with a grade of around 6. Due to their extremely stable electron configuration, these dyes offer excellent resistance to the deteriorating effects of sunlight's UV component [6,17]. Different reactive groups, but a common chromophore, characterize reactive dyes with exceptional light fastness. Reactive dye's light fastness is mostly determined by its chromophore; the composition of the reactive group has no influence on light fastness [18].

5.2 Wash fastness

Reactive dyes generally have a good wash fastness and a rating of around 4-5. This can be determined by the extremely strong covalent bond that exists between the dye molecules and the fiber polymer under alkaline pH conditions during dyeing process [6]. Although once the dyeing process is over, the colors that are now penetrated inside the fibers must be a little resistant to removal by solvent. This requirement may be called wet fastness, and dyes for cellulosic fibers can have a wide range of wet fastness properties [15-16].

5.3 Washing off

Reactive dyes have the ability to react with the hydroxyl groups in water molecules to form dye molecules that are not very substantiative for fiber [6]. After dying, removing any hydrolyzed and unreacted dye is essential. A cotton fabric treated with reactive dyes may need to have less than 0.002% owf of unfixed dye remaining in it. If these dye molecules are not eliminated, the rub fastness may be affected [17]. After washing-off, the remained dye on the fibre is considered as fixed dye of the fibre [15].

5.4 Effect of acids

Alkaline conditions are necessary for the covalent bond to develop between the dye and the fiber. Acids may cause this process to be reversed. Textile fabrics dyed with reactive dyes may be affected by perspiration and surrounding pollution, both of which have a somewhat acidic nature and may cause some fading [6].

5.5 Effect of chlorine

Initially, when reactive dyes were developed, it was discovered that some of them were negatively impacted by chlorine-containing bleaches. Textile materials should be dyed with those dyes that are resistant to chlorine bleach; otherwise, the materials will fade [6].

VI. Conclusion

Among all the dyes, reactive dyes are the most widely used class of synthetic dyes in the dyeing and printing industries because of their great fastness qualities, versatility in application, and wide range of shades. There are many types of reactive dyes that contain distinctive reactive group(s). This paper discussed the components of reactive dye available with different reactive systems that react with subtract to form a strong covalent bond and become an integral part of the fiber. These dyes have entirely different toxicological characteristics after dyeing and fixation due to the elimination of the reactive group. After dyeing, the washing-off process removes all unfixed dye from the surface of fiber through washing and rinsing in order to achieve the high wash-fastness properties. Thus, consumers using fabrics dyed with reactive dyes have not reported any instances of adverse reactions (Chavan, 2013). Therefore, reactive dyes can be an alternative for dyeing and printing of textiles.

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