

# TEXTILE FABRIC'S AND DYES

Touseef Younas<sup>1\*</sup>, Noor Tayyaba<sup>1\*</sup>, Afsheen Ayub<sup>2</sup>, Shaukat Ali<sup>3</sup>

Review paper

UDC: 677.026:667.7

doi: 10.5937/tekstind2103047Y



<sup>1</sup>Faculty of Science, Chemistry Department, University of Agriculture Faisalabad, Pakistan

<sup>2</sup>Government Degree College, Ayub Research, Faisalabad, Pakistan

<sup>3</sup>Faculty of Science, Chemistry Department, University of Agriculture Faisalabad, Pakistan

\*e-mail: noorayub50@gmail.com

**Abstract:** *Textiles sectors serve up the outfit needs of every day and this industry plays a major role in the economy of the country. All the textile fabrics are either natural or synthetic fibers or a blend of both. Different types of dyes are used for different kinds of fabrics depending on the nature and type of the fabric to be dyed, to impart color, modify the fabric to make them more attractive and astonishing. In short, the introduction of synthetic dyes resulted in the demise of a massive natural dye industry. So, it's necessary to classify the different types of dyes with the increase in the number of types and varying dyeing properties so that this would be a best way to understand the different types of dyes, their applicability, fastness and other properties. In this article, a source for the beginners is provided to understand different kind of the textile fabrics and their importance as well as their drawbacks, dyes and their various types, their interaction with the corresponding fabric, their color strength and color fastness properties.*

**Keywords:** Textile industry, Natural fabric, Synthetic fabric, Dyes, Types of dye, Comparative study of natural and synthetic dyes.

## TEKSTILNE TKANINE I BOJE

**Apstrakt:** *Sektori tekstila svakodnevno opslužuju odevne potrebe i ova industrija igra važnu ulogu u ekonomiji zemlje. Sve tekstilne tkanine su prirodna ili sintetička vlakna ili njihova mešavina. Za različite vrste tkanina koriste se različite vrste boja, zavisno od prirode i vrsti tkanine za bojenje, kako bi se prenela boja, izmenila tkanina kako bi bila privlačnija i zadivljujuća. Ukratko, uvođenje sintetičkih boja dovelo je do propasti masovne industrije prirodnih boja. Dakle, potrebno je klasifikovati različite vrste boja sa povećanjem broja vrsta i različitim svojstvima bojenja, tako da bi to bio najbolji način za razumevanje različitih vrsta boja, njihove primenljivosti, postojanosti i drugih svojstava. U ovom članku daje se izvor za početnike kako bi se razumele različite vrste tekstilnih tkanina i njihov značaj, kao i njihove nedostatke, boje i njihove različite vrste, njihova interakcija sa odgovarajućom tkaninom, jačine i postojanosti boje.*

**Ključne reči:** Tekstilna industrija, Prirodna tkanina, Sintetička tkanina, Boje, Vrste boja, Usporedno proučavanje prirodnih i sintetičkih boja.

## 1. INTRODUCTION

Textiles are a significant element of material culture. They may be considered as the yields of technology, as cultural icons, as work of art or as articles of trade. The textile arts are an essential human activity, which express symbolically far what is invaluable in any culture. Textiles serve up the everyday basics of people but also serve to differentiate individuals and the groups of individuals in terms of gender, social class, and status with the group and occupation [1].

Textile industries pay a major fraction to the economy of most of the countries. The large variety and number of products from the textile industry create it the second largest sector of industries after the food manufacturing. The textile industry is every so often regarded as a backbone of the economy of the Islamic Republic of Pakistan. The textile Industry of Pakistan is the fourth biggest Cotton Producer and sixth largest retailer of raw cotton and also the third largest Purchaser [2].

The economy of Pakistan strongly relies on its textile sectors and cotton. The textile industries and cotton processing make up about half of the manufacturing base of country while cotton is primary industrial crop of Pakistan, providing essential income to rural family circles. Entirely, the cotton textile sectors account for 60 percent export receipts and 11 percent of GDP. In short, textile industry is like the backbone for the economy of the country and a source of employment for citizens [3].

erals, while the synthetic fibers are produced by man in the laboratories from the chemical compounds, and each type of the fabric is valued in the textile industry for various reasons [4]. The common examples of the natural fabrics originate from the plant source are linen and cotton while those from the animal source are wool and silk and that of from minerals are asbestos. These fabrics have their natural colors and if incase coloring is necessary, then dyeing is easy [5].

Generally, the natural fabrics are comparatively comfortable to wear. The natural fabrics are environmentally friendly and on burning, it turns into the ash. of these fibers have limited use as compared to the synthetic fibers. There exist chances of the dust and impurities during the manufacturing. Also, the natural fabrics are less durable then the synthetic fabrics [5].

Man-made fibers designed in laboratories are the synthetic fibers. The common Examples of the synthetic fibers are nylon, acrylic and the polyester. They do not have Colors and can be colored as per requirement. The Coloring of the synthetic fibers is difficult as it involves high temperatures usually and larger energy consumption and specific conditions for the dyeing [6]. These fabrics are not much comfortable to wear out as compared to the natural fabrics. The synthetic fabrics are not environmentally friendly because some fibers, like polypropylene is toxic and harmful and on burning, it melts and creates out chemical smell. However, these fibers have fewer chances of impurity and dust in its structure and are more durable than the natural fibers [7].

## 2. NATURAL AND SYNTHETIC FABRICS

All the textile fabrics can be considered as either natural or synthetic fibers or a blend of the natural and synthetic. Both of the types have cons and pros. The natural fibers come from majorly plants and animals and min-

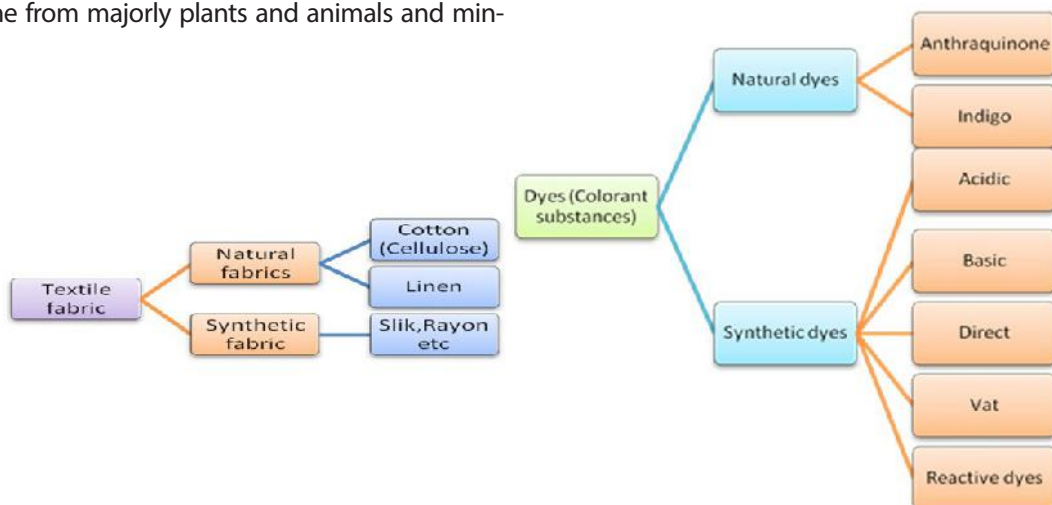


Figure 1: Textile Fabrics

### 3. COTTON

Cotton is natural fabric and one of the most abundant polymers of the nature. Cotton fabric is the purest form of the cellulose which is fine hair of seeds of the plants associated with a special family of plants known as mallow family. Almost ninety percent of cotton is pure cellulose while the cellulosic is present inside the lumens of fiber or on the outer most layer such that in the primary cell wall however the secondary cell wall is pure cellulose [8]. Cotton fabric is naturally cool, soft and hollow fibers which are also named as the absorbents and breathable fibers. The cellulose in the cotton fiber has the highest structural order such that well oriented, febrile and highly crystalline [9].

Cotton fabric is good absorbent such that a good dye absorbent and can also hold water 24 to 27 times of

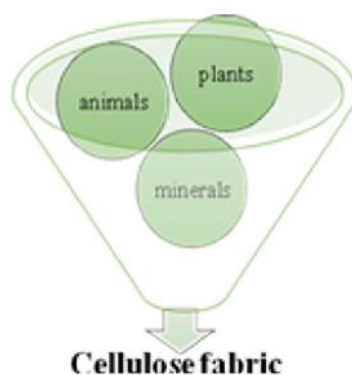
its own weight. It can also bear the high temperatures and abrasion of wear, in short, cotton is comfortable. As the cotton folds, so by mixing it with the polyester or by applying some special permanent finishes, makes the cotton garments to hold proper properties [10]. Cotton fabric is not only used single but also often mixed with the others fibers such as linen, polyester, nylon and wool in order to attain best properties of each fabric [11].

Cotton fibers contain a variety of impurities that should be eliminated. Here is a brief analysis of a pastel cotton fiber. In order to get an effective printing or dyeing, a proper cleans and free of impurities cotton fiber should provide [12]. Here is some impurities and their composition and percentage is mentioned that should be removed before the dyeing of the cotton fabric in order to get best dyeing results [13].

Impurities Analysis	
Component	Percentage
Cellulose	94%
Minerals	1.2%
Proteins	1.3%
Pectin	0.9%
Organic acid	0.8%
Waxes	0.6%
Sugars	0.3%
Other	0.9%

Here is simple way to elaborate the source, categories and structure of the cellulose fabric [14].

- Extraction of cellulose fabric



**Figure 2:** General extraction

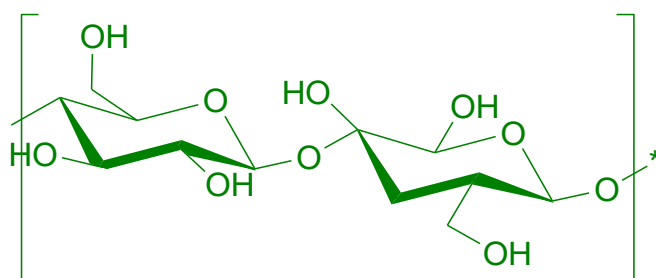
- Types of cellulose fabric



**Figure3:** Types of cellulose fabrics

- Structure of cellulose fabric

It contains a, 3 hydroxyl groups, with formula  $C_6H_{10}O_5$ . As shown



**Figure 4:** General Structure of cellulose fabrics

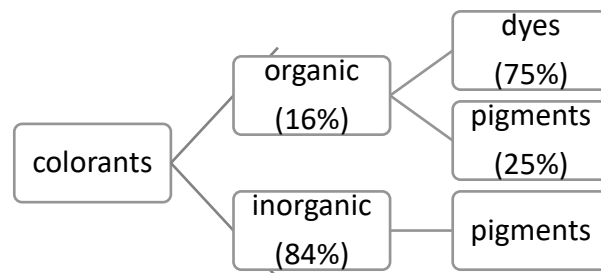
Cellulose is a polysaccharide molecule and -OH position is the point where bonding occur i.e. hydrogen bonding resulting an efficient and effective bonds with the fabric and giving the excellent properties regarding fastness of light, color, washing and rubbing [15]. Conventionally, cleansing of cotton fabric is carried out by the means of high temperature treatments with a solution which contains wetting agent, detergent and alkali. Sometimes, a chelating agent is also added to the cleansing solution so that if there is any heavy metal present in cotton, it will make complex with that metal and hence eliminated [16].

#### 4. DYES

Ever since ancient time, the man has been charmed to color the stuffs of daily use using natural pigments of vegetable, mineral origins, and animal,

or using inorganic salts. Colorants in general, are assumed to consist of both the pigments and the dyestuff. Pigments are referring mostly to inorganic salts or oxides, like chromium and iron oxides, which are commonly spread in powder or crystal form in the application medium [17]. The depressed color properties of pigments hang on the form and the particle size of the pigments [18].

Pigment colorants have a tendency to be the heat stable, lightfast, highly durable, solvent resistant and fast migration. Besides, the pigments are also have poor color strength and brilliance and lean towards to be hard to process [19]. Dyes also called dyestuff are conservatively agreed to speak of an organic molecules which are dissolved in the application medium as the molecular-chromophores. Some examples are coumarin dye, perylene dye, and azo dye [20].



**Figure 5:** Types of colorants

Dyes are substances that can be well-defined in the sense that when added to a substrate, the substances impart color through a process at particular conditions based on the nature of the substrate and that can change with the substrate. Dyes impart their colors by stain or by being absorbed when it is dissolved in a solution [21]. Dyes are usually soluble in water and their ability to impart their color depends on the physical and chemical properties of the substrate. Such substances, with significant coloring ability are extensively utilized for the coloring the several fabrics and stuffs in order to make them attractive, striking, and colorful to deal with the modest environment [22].

Around the world ten million tons of synthetic dyes are produced and numerous industries used these dyes. And it is also projected that above ten thousands different dyes are produced and used by the various industries annually [23].

These dyes are used by a large number of industries including textiles and garments, food, pharmaceutical, cosmetics, photographic, plastics, paint, ink, paper industries and many others [24].

The use of the dyes in the textile industry is of great importance as this is not only being cost-effective but their flexibility of dyes items, towards dyes finishes and shades, rapid turnaround, quick responses makes the textile fabric to look more colorful and stunning. Generally, soluble colorants are used for coloring textiles, paper and other industries and during application process; they impart color by the selective absorption of light [25].

## 5. TYPES OF DYES

Dyes are classified according to the composition or chemical structure such that organic or inorganic, their origin, natural or synthetic, method of application, hue, utilization, their dyeing properties and sometimes, the place of origin, and the name of the manufacturer [26].

Besides the chemical structure, dyes are mainly categorized by the dyeing properties. There are a large number of dyes and a great number of materials and fibers that include colorants in their manufacturing. Definite dyes are used for the particular materials which depends on the dyeing properties such that physical properties of material to be dyed and chemical properties of dye. The Dyeing properties are classified as mordant and chrome, basic or cationic, sulfur, vat, reactive, acid and pre-metalized, direct, azoic, and disperse dyes [27].

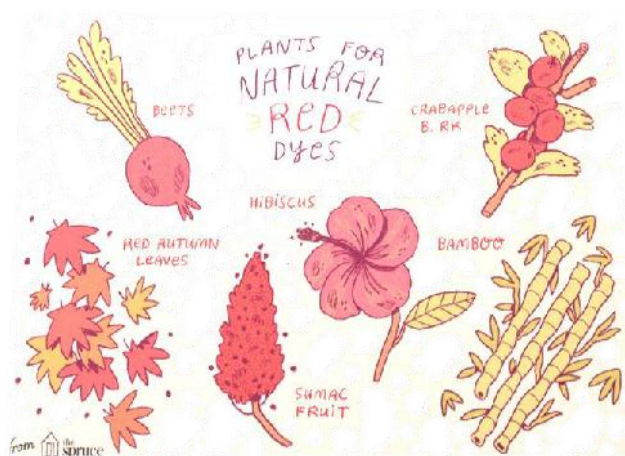
The difference between the natural and synthetic dyes is basically that the synthetic dyes are manufactured chemically while the natural dyes are only obtained from nature. Natural dyes are though free from chemicals are every so often more costly than the chemical or synthetic dyes [28]. Therefore, many textile industries have moved to the chemical or synthetic dyes. Quiet, natural dyes are yet appreciated for their pureness and are still being used for cosmetics, drugs and foods that are human consumption components [29].

## 6. NATURAL DYES

Colors extracts from natural sources have emerged as vital option in contrast to artificial colors. Due to the non-ecfriendly and risky nature of synthetic color, natural colorants has gained worldwide public acceptance towards textile fabrics. For getting great shading quality and high brilliancy of fabric with natural color, job of coloring and chemical stripping can't be denied.

Natural dyes are the dyes gained from the natural resources. Most of the natural dyes are obtained from the plant origins and take out from the barks, roots, berries, wood, flowers, lichens, seeds, leaves and nuts. While some of the natural dyes are obtained from the mineral compounds, shellfish and insects [30].

Until the synthetic dyes were advanced in latter half of the 19th century, the natural dyes were the single source



**Figure 6:** Natural colorants

(<https://www.thespruce.com/mary-marlowe-leverette-2145663>, 2020)

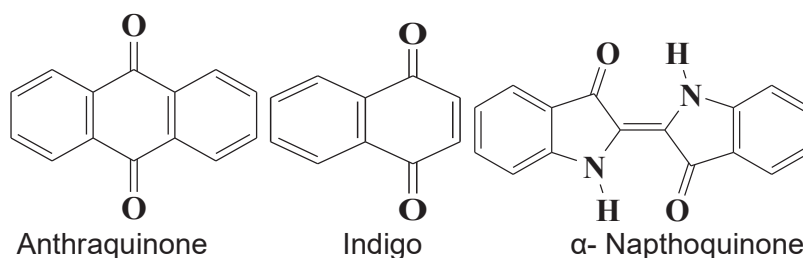
of coloring for the basketry, leather, textiles and other things. A very few of the thousands of the natural dyes come to be commercially significant.

The term dyestuff states to plant or the other material or resources from which dye is obtained [31]. The natural dyes are of two types one is the adjective or the additive dyes. The common example is madder that use a mordant to bond the dye with fibers. The other one is the substantive dyes which bond to the fiber without any use of the mordant as it contains natural mordant called tannin. Some examples of the substantive dyes are cochineal, black walnut and safflower [32].

The mordants are the chemical compounds that form a chemical bridge between dye and the fiber by linking with dye and fiber. all the commercially significant

natural dyes such as cochineal, madder and others are polychromic sense that these dyes produce dissimilar colors with different types of the mordants used [33]. The common mordants are the weak organic acids like tannic or acetic acid and metal salts containing ferrous sulfate, aluminum ammonium or the potassium sulfate and the copper sulfate [34]. Here are some example of natural dyes as shown below...

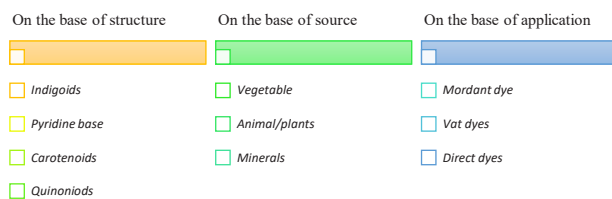
Generally, the fabric which has to be dyed is bubbled in the mordant solution before the dyeing. This is called pre-mordanting. The additional selections comprise of adding mordant to dye-bath or by treating with some other mordant after the dyeing to shift color [35].



**Figure 7:** Common examples of Natural dyes

## 7. CLASSIFICATION OF NATURAL DYE

The colorants are set according to the chemical structure, the process used on them in textile sectors or production sources [36]. The all out portion of natural colors in the textile part is around just 1%, because of manageability and definite specialized problems engaged with the application and production of these colors for example no availability. Natural dyes remain renewable and workable as they are biodegradable but they cannot attain the vast claim from the textile area. Numerous limitations and challenges related with the use of natural dyes. There are a few limitations of natural colors for example unevenness and availability, shading quickness properties, utilization of Non-Eco-friendly mordants for color dyeing, longer coloring time and maintainability (Kadolph, 2008).



**Figure 8:** Classification of Natural products

## 8. SYNTHETIC DYES

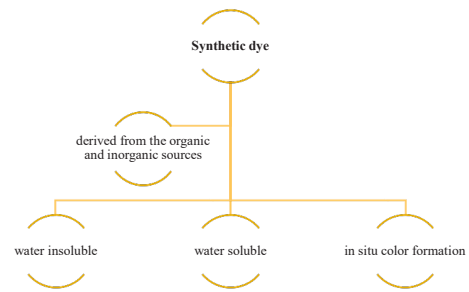
An eighteen years old English chemist named William Henry Perkin was examining for the malarial cure such that synthetic quinine and he accidentally discovered ever first synthetic dye. He noticed that oxidation of aniline might color the silk and then he further investigated about the color stability and color intensity and observed the effect of heat and light over it [37].

Synthetic dyes are the color substances synthesized from the organic compounds. Before the discovery of the synthetic dyes in the mid of the 19th century, the only means for the production of dyestuffs were from the natural resources like roots, insects, flowers, vegetables, mollusks, minerals, and wood [38].

Collections of the natural dye were never exactly similar with respect to intensity and shade. While the synthetic dyes or the dyestuffs can easily be prepared constantly [39].

The synthetic dyes are classified according to their chemical structure or composition, dyeing properties, type of fiber to which the dye are applied, by the shade or hue and by the application method. The interaction of the fiber and dye can be so that the dye molecules might fasten to surface of fiber or may be absorbed by fiber or may interact with the molecules of the fiber [40]. Every

fiber responds in a different way to the dyes applied. Fiber amendments react in a different way to same dye as well. Within the single dye grouping, different colorfastness will observed for the different hues [41]. Synthetic dyes are classified according to their utilization in dyeing process, they react with the fabric directly or through absorption, by a chemical interaction. It also classified, via the presence of chromophoric groups, their solubility when they are applicable to the fabric etc. The source and types of synthetic or man-made dyes according to their solubility and color formation are shown in flow-chart as following.



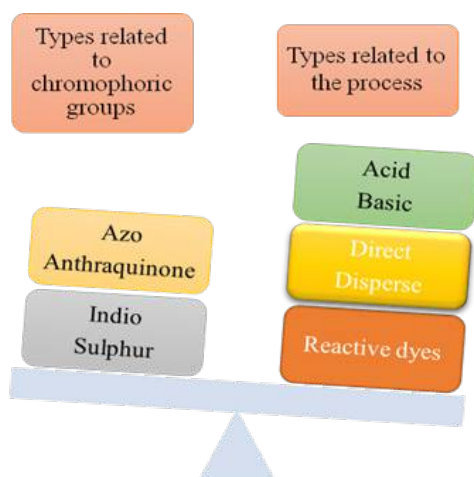
**Figure 9:** Classification of Synthetic dyes

On the basis of the structure, dye consists of three parts that are chromogen, chromophore, and auxochrome which are resolvable in particular conditions under definite circumstances. Unsaturated assemblage of chromophore that one first captivates light and then redirects it at a definite approach to provide shade e.g. nitro, keto, azo, etc; chromogen preserves chromophore and plays a fundamental part to regulate the shade with tendency for fiber, stability, fastness etc. while auxochrome is a replaced basic or acidic assembly in the structure dye to exaggerate the penetration of shade of  $-OH$ ,  $-COOH$ , etc [42].

Here are some dyes which are classified according to the chemical structure or composition, by the generic name by its CI number (color index constitution number) which is an indication to the chemical structure [43].

### 8.1. Acid Dyes

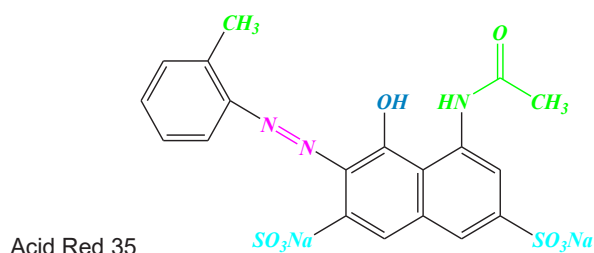
The acid or anionic dyes are the dyes which are water soluble and are applied to silk certain modified acrylic wool, polyester fibers, modified rayon and nylon. Those Fibers that can be damaged by the acids like cotton and cellulose cannot be dyed with these dyes. These dyes are used in the acidic bath though they may differ in their chemical composition. The dyes of this class gives bright colors appearance and have broad color range but varies with respect to the colorfastness [44].



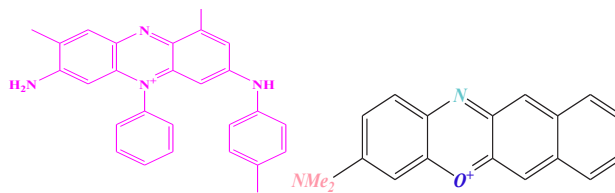
**Figure 10:** Classification of Synthetic dyes relevant to chromophoric group and process

### 8.2. Basic Dyes

Basic or cationic dyes are bright but poor in colorfastness. These dyes have their restricted use on protein fibers and cellulosic fiber. However, silk and Wool can be dyed with the basic dyes in the acid dye bath. Basic dyes are applied to the limited class of cellulosic and protein fabrics having poor color-fastness. These dyes are salts generated dyes having amino as a basic group. At the time of reaction with salts, it convert in to  $\text{NH}_2$  and  $\text{HCl}$  salts groups. After this it dissociate into cations and anions. The cations are the dyes and anions are the acidic in nature. Mauvien: The first syntetic dye mauvein belong to this class of dye [45]. It was an unplanned discovery. Discovered, during the experiment which was conducted for the treatment of malaria. It was a mixture which was linked with four allied aromatic compound each compound was different with one another by numbering and placement of methy-group.



**Figure 11:** Acid Red 35



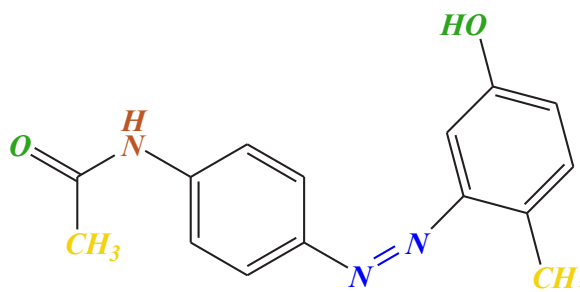
**Figure 12:** Mauvein & CI Basic Blue 6

They are useful for basic dye able deviations of polyester and nylon. Basic brown 1 is the example of basic dye, which is easily protonated according to dyeing conditions of pH 2 to 5 [46, 47].

### 8.3. Azoic Dyes

Azoic dyes are also called the naphthol dyes, are manufactured in the interior fiber of the cellulose fibers. The cellulose fiber is saturated with the one constituent of the dye and then treated with another component and thus developing the dye [48].

When these two components are combined under the appropriate conditions such that a water bath at low temperature is employed, then within the fiber, an insoluble and large colored molecule is formed. Since the color is inside the fiber, so the colorfastness is brilliant [49].

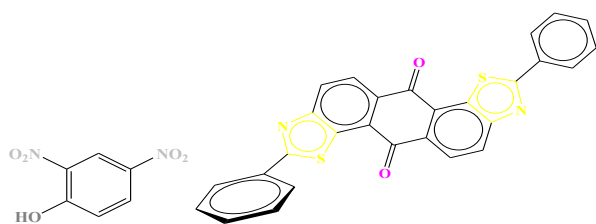


**Figure 13:** Disperse yellow 3

### 8.4. Sulfur Dye

Sulfur dye has deep color tone, excellent washing resistance, and poor sun resistance. This dye may be rayon, linen and cotton, but they are not very bright. Main problem with sulfur dye is that they soften the stuff or deteriorate its structure composition, making it susceptible to breakage. The sulfur dye is pragmatic to the fabric from alkaline reduction wherein sodium sulphide is used as a reducing agent. These dyes are less expensive and having better light fastness [50].

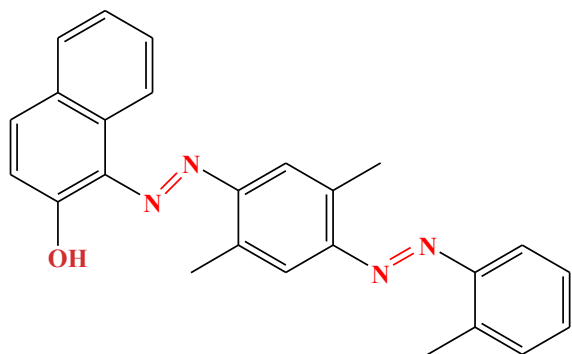




**Figure 14:** Sulphur Black 1 & Novatic yellow 5G

### 8.5. Solvent Dye

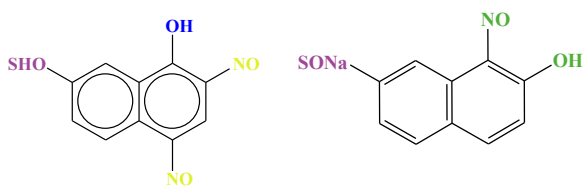
Solvent dyes are soluble in chlorinated hydrocarbons, alcohols or liquid ammonia but insoluble in water. These colors are functional by liquefying in the objective, which is always lipid or non-polar flush. Every dye named by the subsequent array: - Solvent + primary color + Number. They are useful to color synthetic materials, gasoline, plastics, waxes and oils[51].



**Figure 15:** Solvent red 26

### 8.6. Nitro Dye

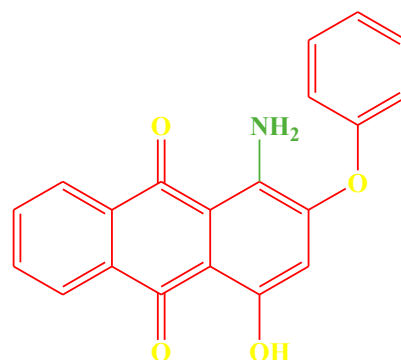
A nitro dye is a multivariate derivative of phenol containing one nitro group in the para or ortho position toward the hydroxy group. It consists of two or more than two aromatic rings (benzene, naphthalene)[52].



**Figure 16:** Naphthol yellow-S & Naphthol-green-B

### 8.7. Disperse Dyes

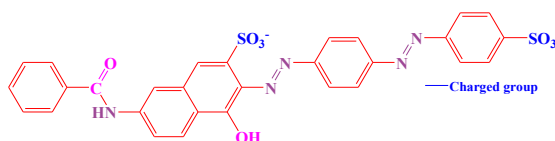
Disperse dyes are first synthesized for the dyeing of acetate fibers. These fibers are hydrophobic fibers such that they have no or minor attraction for the water soluble dyes. A method for the dyeing of such hydrophobic fibers by the means of dispersing colored organic elements in the water in the presence of a surfactant was introduced. The colorfastness of these dyes is good to excellent [53].



**Figure 17:** Dispersed red 60

### 8.8. Direct Dyes

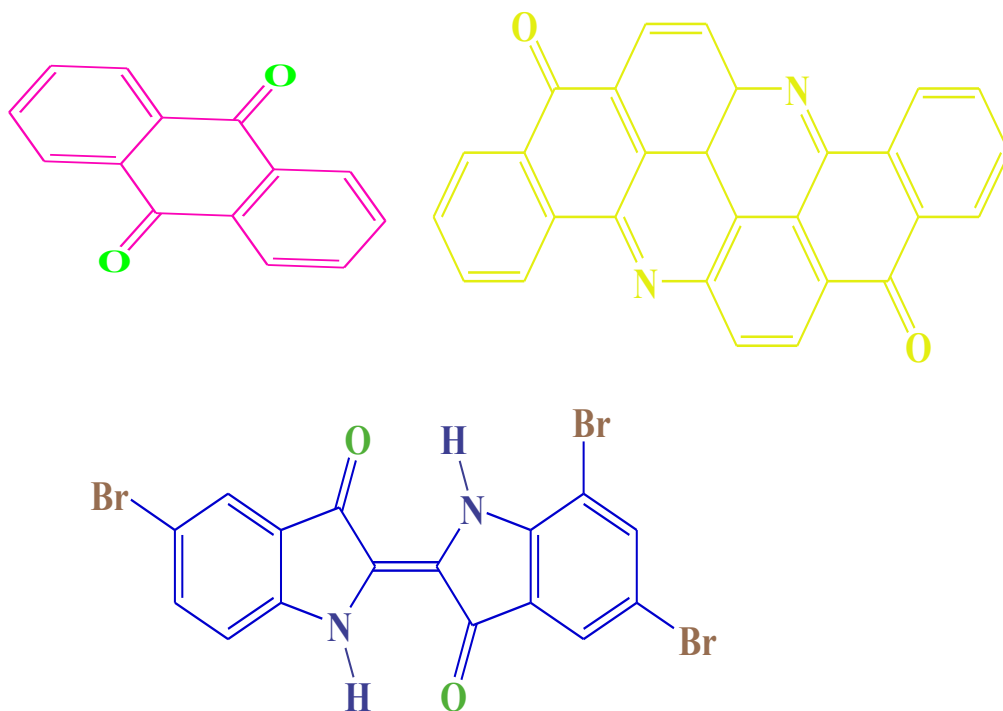
Direct or substantive dyes are soluble and show their affinity for the cellulose fiber. These dyes frequently have an azo bond - N = N - and molecular mass. An electrolyte and salt is added to the dye-bath to regulate the absorption rate of dye by fiber. Then the dye is engaged by the fiber and the colorfastness is good to the light but colorfastness to washing is not good. The Developed direct dyes have a superior wash fastness but still poorer light fastness as compared to the direct dyes. Both types of dyes are used on low cost fabrics [54].



**Figure 18:** Direct red 81

### 8.9. Vat Dyes

The word 'vat dyes' was derived from large vessels that were used to spread over the dye. . Vat dyes have well to excellent color fastness and an incomplete color range. These dyes are mostly used to dye the cotton work clothes, drapery fabrics sportswear, cotton polyester and blends prints [55].

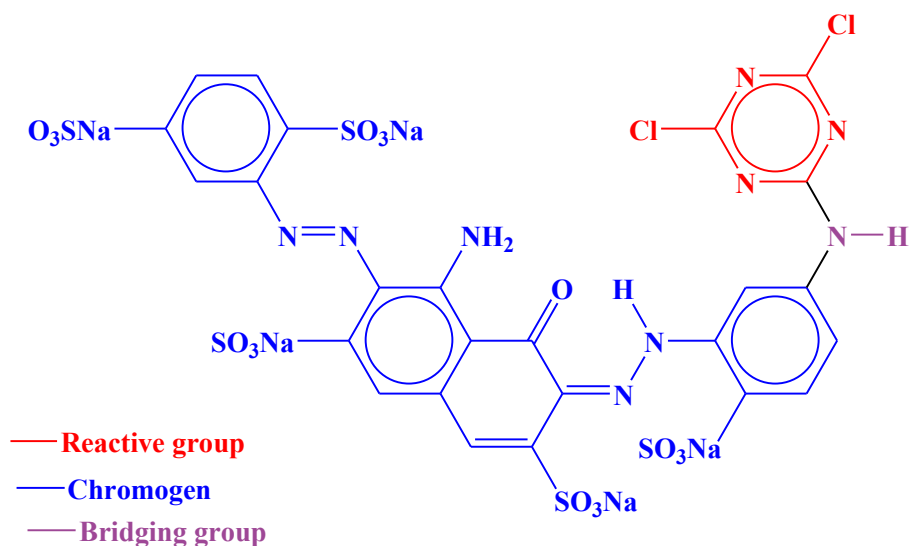


**Figure 19:** Anthraquinone vat dye, Vat Blue & Flavanthrones

### 8.10. Reactive Dyes

These dyes were introduced to the industry in 1956. Reactive or fiber-reactive dyes attach with the fiber substrate by the addition or substitution reactions. The color strength is high and cannot be detached if

applied appropriately. The resulted colors are bright and have very good colorfastness but can be damaged by the chlorine bleaches [56]. These reactive dyes can color the cellulosic fibers such that cotton, viscose rayon and flax, nylon, wool, and silk. Reactive dyes are used for the blend of cellulosic and polyester fibers by the combination with the disperse dyes



**Figure 20:** Reactive blue

## 9. CONCLUSION

Textile plays an important role in material culture and it also serves the necessities of daily life. The different types and quality of the textile fabric differentiate different classes of the society. These fabrics may be either natural fibres or synthetic fibres. Since certain fibres such as polypropylene are poisonous and dangerous as the synthetic fabrics are not environmentally friendly. However, these fibres on the other hand, are less likely to have impurities and dust in their composition and are more resilient than natural fibres. With the help of synthetic fabrics, we are able to synthesize the fabrics with desired characteristic. In the synthesis of the textile fabrics, the dyes play an important role in the finishing and final look of the fabric. The use of dyes in the textile industry are really significant because they are not only cost-effective but they also have a lot of flexibility in terms of dyes pieces, dye finishes and colors, fast dispatch and quick responses which makes the fabric-look more exciting and beautiful. These dyes may be either natural or synthetic. In the modern era, the synthetic dyes are manufactured in millions of tones around the world every year and they are used in a variety of industries. Each year, it is estimated that over 10,000 different dyes are manufactured and used by numerous factories around the world. These dyes are used by a broad number of industries, including textiles and clothing, food, pharmaceutical, cosmetics, photography, plastics, paint, ink, paper, and many others.

In the textile industry, during the processing of the cotton fabric, cotton absorbs dye well and can handle up to 27 times its own weight in water. Cotton fabrics have a number of impurities that must be removed before processing. To have the best dyeing results, the impurities should be washed before the cotton cloth is dyed. Traditionally, high-temperature baths with a solution containing a wetting agent, detergent and alkali have been used to clean cotton fabrics. After the removal of impurities the fabric is converted for successful printing or dyeing. Each fiber reacts in a different way to the colors or dye added such that the interaction between fiber and dye is responsible for the attaching of the dye with fiber. As compare to the types of dyes it was conclude that basic dyes can be used in the acidic bath though they may differ in their chemical composition and are applied to silk certain modified acrylic wool, polyester fibers, modified rayon, and nylon. Those fibers that can be damaged by the acids like cotton and cellulose cannot be dyed with these dyes. Vat dyes have well to excellent color fastness, but having an incomplete color range. On the other hand, reactive dyes are a well-known class of dyes having good fastness, attach with the fiber substrate by the addition or substitution reactions. The color power is high and cannot be detached if applied properly to the fiber substrate. At the end, an introduction of machine learning (ML) in

textile industry is presented. We hope so this article will be helpful to provide you a complete data without the wastage of time by searching each topic separately. Moreover this manuscript highlights the importance of textile fabrics, their types, dyes and the types of dyes for the ease offer searchers. In short this article helps the researcher to know about the basic of fabric, dyes and their types in a short time and there is no need to search and find the basic separately.

## REFERENCES

- [1] Adams, C. D., Gorg, S. (2002). Effect of pH and gas-phase ozone concentration on the decolorization of common textile dyes. *Journal of environmental engineering*, 128 (3), 293-298
- [2] Agrawal, P. B. (2005). The performance of cutinase and pectinase in cotton scouring. University of Twente.
- [3] Agrawal, P. B., Nierstrasz, V. A., Klug-Santner, B. G., Gubit, G. M., Lenting, H. B., & Warmoeskerken, M. M. (2007). Wax removal for accelerated cotton scouring with alkaline pectinase. *Biotechnology Journal: Healthcare Nutrition Technology*, 2 (3), 306-315.
- [4] Aguilar, Z. G., Brillas, E., Salazar, M., Nava, J. L., Sirés, I. (2017). Evidence of Fenton-like reaction with active chlorine during the electrocatalytic oxidation of Acid Yellow 36 azo dye with Ir-Sn-Sb oxide anode in the presence of iron ion. *Applied Catalysis B: Environmental*, 206, 44-52.
- [5] Ali, M., Courtenay, P. (2014). Evaluating the progress of the UK's Material Recycling Facilities: A mini review. *Waste Management & Research*, 32(12), 1149-1157.
- [6] Ali, S., Mughal, M. A., Shoukat, U., Baloch, M. A., Kim, S. H. (2015). Cationic starch (Q-TAC) pre-treatment of cotton fabric: influence on dyeing with reactive dye. *Carbohydrate polymers*, 117, 271-278.
- [7] Arooj, F., Ahmad, N., Chaudhry, M. N. (2015). A pilot-scale application of ozone to bleach raw cotton fabric using various additives. *Ozone: Science & Engineering*, 37(3), 203-215.
- [8] Arooj, F., Ahmad, N., Shaikh, I. A., Chaudhry, M. N. (2014). Application of ozone in cotton bleaching with multiple reuse of a water bath. *Textile Research Journal*, 84(5), 527-538.
- [9] Asaadi, S., Hummel, M., Hellsten, S., Härkäsalmi, T., Ma, Y., Michud, A., et al. (2016). Renewable high-performance fibers from the chemical recycling of cotton waste utilizing an ionic liquid. *ChemSusChem*, 9(22), 3250-3258.
- [10] Becerir, B. (2011). Assessment of the results of different color difference formulae under different illuminants by wash fastness tests. *Fibers and Polymers*, 12(7), 946.

- [11] Bechtold, T., Maier, P., Schrott, W. (2005). Bleaching of indigo-dyed denim fabric by electrochemical formation of hypohalogenites in situ. *Coloration technology*, 121(2), 64-68.
- [12] Bilińska, L., Żyłła, R., Smółka, K., Gmurek, M., Ledakowicz, S. (2017). Modeling of Ozonation of CI Reactive Black 5 through a Kinetic Approach. *Fibres & Textiles in Eastern Europe*, 25, 5(125): 54-60.
- [13] Chatha, S. A., Mallhi, Al. Hussain, A. I., Asgher, M., Nigam, P. S. (2014). A biological approach for color-stripping of cotton fabric dyed with CI reactive black 5 using fungal enzymes from solid state fermentation. *Current Biotechnology*, 3(2), 166-173.
- [14] Bunko, K., Kennedy, J. F., (2007). Menachem Lewin (Ed.), *Handbook of fiber chemistry*, CRC Press, Boca Raton, FL, USA, Elsevier.
- [15] Hearle, J.W., Morton, W. E., (2008). *Physical properties of textile fibres*. Elsevier.
- [16] Chattopadhyay, D., Chavan, R., Sharma, J.K. (2007). Salt-free reactive dyeing of cotton. *International Journal of Clothing Science and Technology*, 19(2), 99-108.
- [17] Chung, C., Lee, M., Choe, E. K. (2004). Characterization of cotton fabric scouring by FT-IR ATR spectroscopy. *Carbohydrate Polymers*, 58(4), 417-420.
- [18] Dai, Q., Xia, Y., Chen, J. (2016). Mechanism of enhanced electrochemical degradation of highly concentrated aspirin wastewater using a rare earth La-Y co-doped PbO<sub>2</sub> electrode. *Electrochimica Acta*, 188, 871-881.
- [19] El, Shafie, A., Fouda, M. M., Hashem, M. (2009). One-step process for bio-scouring and peracetic acid bleaching of cotton fabric. *Carbohydrate polymers*, 78(2), 302-308.
- [20] Farinos, R. M., Ruotolo, L. A. (2017). Comparison of the electrooxidation performance of three-dimensional RVC/PbO<sub>2</sub> and boron-doped diamond electrodes. *Electrochimica Acta* 224, 32-39.
- [21] French, A. D. (2014). Idealized powder diffraction patterns for cellulose polymorphs. *Cellulose*, 21(2), 885-896.
- [22] Jung, B., Safan, A., Duan, Y., Kaushik, V., Batchelor, B., Abdel-Wahab, A. (2018). Removal of arsenite by reductive precipitation in dithionite solution activated by UV light. *Journal of Environmental Sciences*, 74, 168-176.
- [23] Keqiang, C., Perkins, W. S., Reed, I. E. (1994). Dyeing of cotton fabric with reactive dyes using ozonated, spent dyebath water. *Textile Chemist and Colorist*, 26, 25-25.
- [24] 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.
- [25] Körlü, A. (2018). Use of ozone in the textile industry. *Textile Industry and Environment*, IntechOpen.
- [26] Long, J. J., Cui, C. L., Zhang, Y. Q., Yuan, G. H. (2015). Clean fixation of dye on cotton in supercritical carbon dioxide with a heterogeneous and phase transfer catalytic reaction. *Dyes and Pigments*, 115, 88-95.
- [27] Mu, B., Liu, L., Li, W., Yang, Y. (2019). High sorption of reactive dyes onto cotton controlled by chemical potential gradient for reduction of dyeing effluents. *Journal of environmental management*, 239, 271-278.
- [28] Neppolian, B., Choi, H., Sakthivel, S., Arabindoo, B., Murugesan, V. (2002). Solar/UV-induced photocatalytic degradation of three commercial textile dyes. *Journal of hazardous materials*, 89(2-3), 303-317.
- [29] Oturan, M. A., Aaron, J. J. (2014). Advanced oxidation processes in water/wastewater treatment: principles and applications. A review. *Critical Reviews in Environmental Science and Technology*, 44(23), 2577-2641.
- [30] Pensupa, N., Leu, S. Y., Hu, Y., Du, C., Liu, H., et al., (2017). Recent trends in sustainable textile waste recycling methods: Current situation and future prospects. *Chemistry and Chemical Technologies in Waste Valorization*. Springer, 189-228.
- [31] Rauf, M., Meetani, M., Hisaindee, S. (2011). An overview on the photocatalytic degradation of azo dyes in the presence of TiO<sub>2</sub> doped with selective transition metals. *Desalination*, 276(1-3), 13-27.
- [32] Rizvi, H., Ahmad, N., Yasar, A., Bukhari, K., Khan, H. (2013). Disinfection of UASB-Treated Municipal Wastewater by H<sub>2</sub>O<sub>2</sub>, UV, Ozone, PAA, H<sub>2</sub>O<sub>2</sub>/Sunlight, and Advanced Oxidation Processes: Regrowth Potential of Pathogens. *Polish Journal of Environmental Studies*, 22(4). 1153-1161.
- [33] Sargunamani, D., Selvakumar, N. (2006). A study on the effects of ozone treatment on the properties of raw and degummed mulberry silk fabrics. *Polymer degradation and stability*, 91 (11), 2644-2653.
- [34] Sharma, S., Buddhdev, J., Patel, M., Ruparelia, J. P. (2013). Studies on degradation of reactive red 135 dye in wastewater using ozone. *Procedia Engineering*, 51, 451-455.
- [35] Tokatlı, K., Demirdöven, A. (2018). Optimization of chitin and chitosan production from shrimp wastes and characterization. *Journal of food processing and preservation*, 42(2), 13494.
- [36] Perkin, A. G., Everest, A. E., (1918). *The natural organic colouring matters*. Longmans, Green and Company.
- [37] Topalovic, T., Nierstrasz, V. A., Bautista, L., Jovic, D., Navarro, A., Warmoeskerken, M. M. (2007). Analysis of the effects of catalytic bleaching on cotton. *Cellulose*, 14(4), 385-400.

- [38] Vasconcelos, V. M., Ponce-de-León, C., Nava, J. L., Lanza, M. R. (2016). Electrochemical degradation of RB-5 dye by anodic oxidation, electro-Fenton and by combining anodic oxidation–electro-Fenton in a filter-press flow cell. *Journal of Electroanalytical Chemistry*, 765, 179-187.
- [39] Wedin, H., Niit, E., Mansoor, Z. A., Kristinsdottir, A. R., de la Motte, H., Jönsson, C., Östlund, Å., Lindgren, C. (2018). Preparation of viscose fibres stripped of reactive dyes and wrinkle-free crosslinked cotton textile finish. *Journal of Polymers and the Environment*, 26(9), 3603-3612.
- [40] Xie, C. F., Long, J., Tang, R. C. (2010). Stripping of reactive dyed cotton with UV/H<sub>2</sub>O<sub>2</sub> system under low temperature. *Dyeing & Finishing*, 4.
- [41] Yigit, I., Eren, S., Eren, H. A. (2018). Ozone utilisation for discharge printing of reactive dyed cotton. *Coloration Technology*, 134(1), 13-23.
- [42] Chakraborty, J. (2015). *Fundamentals and practices in colouration of textiles*. WPI Publishing.
- [43] Zhou, M., Särkkä, H., Sillanpää, M. (2011). A comparative experimental study on methyl orange degradation by electrochemical oxidation on BDD and MMO electrodes. *Separation and Purification Technology*, 78(3), 290-297.
- [44] Zhu, C., Shi, J., Xu, S., Ishimori, M., Sui, J., Morikawa, H. (2017). Design and characterization of self-cleaning cotton fabrics exploiting zinc oxide nanoparticle-triggered photocatalytic degradation. *Cellulose*, 24(6), 2657-2667.
- [45] Akramov, K., Mukhitdinova, J. (2020). The importance of obtaining natural dyes. *Asian Journal of Multidimensional Research (AJMR)*, 9(5), 424-435.
- [46] Wang, S., Li, H., Xu, L. (2006). Application of zeolite MCM-22 for basic dye removal from wastewater. *Journal of colloid and interface science*, 295(1), 71-78.
- [47] Puchtler, H., Sweat, F., Kuhns, J. G. (1964). On the binding of direct cotton dyes by amyloid. *Journal of Histochemistry & Cytochemistry*, 12(12), 900-907.
- [48] Gordon, S., Hsieh, Y. I. (2006). *Cotton: Science and technology*. Woodhead Publishing.
- [49] Haslinger, S., Wang, Y., Rissanen, M., Lossa, M. B., Tantt, M., Ilen, E., Määttä, M., Harlin, A., Hummel, M., Sixta, H. (2019). Recycling of vat and reactive dyed textile waste to new colored man-made cellulose fibers. *Green Chemistry*, 21(20), 5598-5610.
- [50] Nguyen, T. A., Juang, R. S. (2013). Treatment of waters and wastewaters containing sulfur dyes: a review. *Chemical engineering journal*, 219, 109-117.
- [51] Jhong, H. R., Wong, D. S. H., Wan, C. C., Wang, Y. Y., Wei, T. C. (2009). A novel deep eutectic solvent-based ionic liquid used as electrolyte for dye-sensitized solar cells. *Electrochemistry Communications*, 11(1), 209-211.
- [52] Bhatti, H. S., Seshadri, S. (2004). Synthesis and fastness properties of styryl and azo disperse dyes derived from 6-nitro substituted 3-aryl-2-methyl-4 (3H)-quinazolinone. *Coloration technology*, 120(4), 151-155.
- [53] Feng, C., Sultana, N., Sui, X., Chen, Y., Brooks, E., Ankeny, M. A., Vinuesa, N. R. (2020). High-Resolution Mass Spectrometry Analysis of Reactive Dye Derivatives Removed from Biodegraded Dyed Cotton by Chemical and Enzymatic Methods. *AATCC Journal of Research*, 7(1), 9-18.
- [54] Index, C. (1971). *Society of Dyers and Colourists and American Association of Textile Chemists and Colorists. Colour Index*.
- [55] Niu, T., Wang, X., Wu, C., Sun, D., Zhang, X., Chen, Z., Fang, L. (2020). Chemical Modification of Cotton Fabrics by a Bifunctional Cationic Polymer for Salt-Free Reactive Dyeing. *ACS omega*, 5(25), 15409-15416.
- [56] Kiernan, J. A. (2001). Classification and naming of dyes, stains and fluorochromes. *Biotechnic & histochemistry*, 76(5-6), 261-278.
- [57] Sala, M., López, Grima, V., Gutiérrez-Bouzán, C. (2014). Photo-electrochemical treatment of reactive dyes in wastewater and reuse of the effluent, Method optimization. *Materials*, 7(11), 7349-7365.
- [58] Tayyaba, N., Younas, T., Ali, S. (2021). Chemical Color Stripping of Cellulose Fabric dyed with Reactive dyes. (*IJESIR*) *International Journal of Science and Innovative Research*, 02(05), 4-16

---

Primljeno/Received on: 31.05.2021.

Revidirano/ Revised on: 12.06.2021.

Prihvaćeno/Accepted on: 20.06.2021.

---

© 2021 Authors. Published by Union of Textile Engineers and Technicians of Serbia. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution 4.0 International license (CC BY) (<https://creativecommons.org/licenses/by/4.0/>)