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Application of natural dye on synthetic fabrics: A review

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Abstract
Natural dyes are derived from plants, invertebrates, or minerals. The majority of natural dyes are vegetable dyes from plant sources-roots, berries, bark, leaves, and wood—and other organic sources such as fungi and lichens. Natural dyes are mostly used to dye natural fibers like cotton, wool, silk, jute etc. But very little information is available on dyeing of synthetic filament like polyester, acrylic, nylon etc. This paper is a comprehensive review of application of natural dyes on synthetic fabrics. The dyeing of synthetic fabrics with natural dyes requires pre-treatments to generate hydrophilic groups. This paper highlights about the various pre treatment processes used to carry out dyeing with natural dyes on synthetic fabrics. The paper also reviewed the properties of dyed synthetic fabrics.

Keywords: Natural dyes, synthetic fiber, pre treatments, fastness

1. Introduction
Dyeing is the process of adding colour on textile products. The main purpose of the dyeing on textile material can be increase value addition, improvement of the performance and fulfill of the customer's needs. Textile dyeing industry at present uses excessive amount of synthetic dyes to meet the required coloration of global consumption of textiles due to cheaper prices, wider ranges of bright shades, and considerably improved fastness properties in comparison to natural dyes. Dyeing is an ancient art which predates written records. Its practice could be traced back during the Bronze Age in Europe [1]. That time, textile was dyed from natural sources like fruits, plants, berries etc.

Natural dyes are known for their use in colouring of food substrate, leather as well as natural fibers like wool, silk and cotton as major areas of application since pre-historic times [2]. Although this ancient art of dyeing textiles with natural dyes withstood the ravages of time, but due to the wide availability of synthetic dyes at an economical price, a rapid decline in natural dyeing continued. However, even after a century, the uses of natural dyes never erode completely and they are being still used in different places of the world. Thus, natural dyeing of different textiles and leathers has been continued mainly in the decentralized sector for specialty products besides the use of synthetic dyes in the large scale sector for general textiles/apparels [3].

But the production of synthetic dyes is dependent on petrochemical source, and some of these dyes contain carcinogenic amines. The application of such dyes causes serious health hazards and influences negatively the eco-balance of nature. Moreover, many countries already imposed stringent environment standards over these dyes. In this situation, a higher demand is put towards the greener alternatives or agricultural residues. As a result, natural dyes are among the promising options for developing a greener textile dyeing process and such interest is reflected to the increased number of recent publications [4]. In fact most of the commercial dyers and textile export houses have started re-looking to the maximum possibilities of using natural dyes for dyeing and printing of different textiles for targeting niche market.

Natural dyes produce very uncommon, soothing and soft shades as compared to synthetic dyes. Plant leaves, fruits and other are potential sources of natural dyes because of their easy availability and abundant nature. For successful commercial use of natural dyes for any particular fibers, the appropriate and standardized techniques for dyeing for that particular fiber-natural dye system need to be adopted. Thus, relevant scientific studies and its output on standardization of dyeing methods, dyeing process variables, dyeing kinetics and test of standardization of dyeing methods, dyeing process variables, dyeing kinetics and test of

compatibility of selective natural dyes have become very important [5]. This paper presents some relevant scientific overview on dyeing of synthetic textiles with natural dyes and related issues.

For success of commercial use of natural dyeing on synthetic fibers it should be essential to produced new shades with acceptability of fastness behavior. So, there is need for using of appropriate scientific techniques and methods. Before producing uncommon shades with balance colour fastness and eco performing textile, there has also need for reinvestigation of traditional process of natural dyeing in each step of treatment (preparation, mordant, fastness). Presented paper carried out application of natural dyes on polyester, nylon and acrylic fibers and focused on type of natural dyes and sources, understanding the application of dyes and colour fastness property.

2. Application of Natural Dyeing on Polyester Fabric

Polyester is a synthetic polymer made of purified terephthalic acid (PTA) or its dimethyl ester dim ethyl (DMT) and monoethylene glycol (MEG) [6]. Polyester is hydrophobic in nature and quickly dry. The lack of polarity and the very crystalline structure resists the entry of water molecules into the polymer system. So, when polyester fiber colourant with natural dyes, it should be pre treated. Generally it can be treated with Plasma, Ozone, Mordant, Alkalis or Heating before dyeing.

2.1 Pre treatment processes used for Polyester Fabric

2.1.1 Plasma treatment is a surface modification technology through high / low temperature offers innovative solutions to adhesion and wetting problems. Plasma treatment is a dry and eco-friendly technology, which offers an attractive, alternative to add new functionalities such as water repellence, long-term hydro-philicity, mechanical, electrical and antibacterial properties as well as biocompatibility due to the nano-scaled modification on textiles and fiber.

Various type of plasma treatments are used on textile according to fiber, finishing or requirement such as oxygen plasma and air plasma are used for hydrophilic finish and depth of shed of PET or PP fiber and SiC14 plasma used for dyeing improvement of PET [7].

Motaghi *et al* [8] have studied in Plasma Sputtering Treatment. The design of the system is shown in Figure 1. Samples were placed on the anode, and exposed to argon plasma in a cylindrical glass tube. The chamber was evacuated to a pressure of 2×10-5 Torr, using rotary and diffusion pumps, and then argon gas was introduced into the chamber up to a pressure of 2×10-2 Torr. Voltage was kept at 2000 V and the discharge current was about 220 mA. The duration of Cu deposition was 3, 5 minutes for different samples. By this treatment, one part of polyester/wool fabric samples was coated with copper.

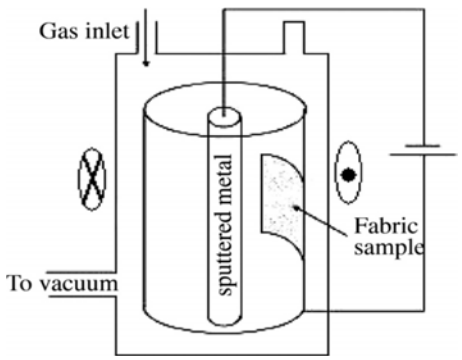

Fig 1: Plasma Sputtering System used for Pretreatment of Polyester

2.1.2 Ozone treatment: Ozone pretreatment activates and improves dye ability of polyester and nylon fibers [9]. Elnagar *et al* [10] have studied, fabrics are pretreated with UV/ozone for different periods of time ranged from 5 min to 120 min. UV/O_3 irradiation was carried out using high intensity; low-pressure mercury lamp without outer envelope (LRF 02971, 200 watts, 220 volts, made in Poland) was placed in a cubic box of side length 60 cm. Samples' strips were hanged around the source at a distance (~20 cm), for different periods 5, 20, 50, 110, and 120 minutes, respectively.

2.1.3 Mordant: Mordants are "metallic salts" that are used in natural dyeing to help set the dye pigment and improve color and light fastness. The word comes from the Latin word "mordere" meaning "to bite" [11]. There are many types of dye mordant such as - tannic acid, alum, urine, chrome alum, sodium chloride, aluminum, chromium, copper, iron, iodine, potassium, sodium and tin. The type of mordant used changes the shade obtained after dyeing and also affects the fastness property of the dye. There are following types of application of mordant:

- Pre-mordant (on-chrome): The substrate is treated with the mordant and then dyed.
- Meta-mordant (meta-mordant): The mordant is added in the dye bath itself.
- Post-mordant (after-chrome): the dyed material is treated with a mordant.

Mordant solution significantly improves the recognized measurable qualities of naturally dyed fibers, including light and wash-fastness. Mohammad A. S. [12] has studied, sodium chloride along with copper sulfate treated as mordant on polyester fiber before dyeing. Ado A. *et al* [13] have studied, three mordanting techniques were adopted before dyeing:

- In Pre-mordanting technique: Fabrics were mordanted with metal salts and myrobolan (3% o.w.f) prior to dyeing. It was carried out at 60 °C for 30 minutes with material to liquor ratio of 1:20.
- In Simultaneous mordanting technique: Fabric were treated with both dye extracts and metal salts concurrently (3% o.w.f) at 60 °C for 30 minutes with material to liquor ratio of 1:20.
- In Post-mordanting technique: Fabrics were dyed with dye extracts and samples were taken out of the bath, squeezed and used for treatment with (3% o.w.f) metal salts without washing. Mordanting was carried out at 60 °C for 30 minutes with material to liquor ration of 1:20

Kundal *et al* [14] have studied, three synthetic mordants and one natural mordant were used for mordanting viz. Potassium Aluminium sulphate, Stannous Chloride, Ferrous sulphate and Tannic acid, in different stages of mordanting: pre – mordanting, post- mordanting and simultaneous mordanting.

- In Pre-mordanting stage: Polyester Fabric was treated with mordant for 30 minute at 60 °C. The dyeing was carried out at 1:30 MLR (material to liquor ratio), for 40 min at 80 °C. Dyeing and mordanting is done by using Rota-Dyeing machine. As we know that synthetic mordants are very toxic and their maximum use can create an environmental issue so only 1% of mordanting was done which is a permissible limit.
- In Post-mordanting stage: In this method both the fabric were dyed first then mordanting as the method used above and rinsed in hot and then cold water and finally treated with mordant solution for 30 minute at 60 °C and rinsed.

- In Simultaneous-mordanting stage: 1 ml of 1% mordant is mixed with 30 ml of dye extract and then 1 gm of fabric is dyed with it for 40 minutes at 60 °C.

2.1.4 Alkalis: An alkali can be defined as a base that dissolves in water. A solution of a soluble base has a pH greater than 7.0. M.F. Shahin *et al* [15] have studied Polyester samples were treated with aqueous solution of NaOH (12%) at L.R. 1:50 at different degrees of temperatures (50-80̊ C) and for various durations (30 -120 min.) before dyeing. The treated samples were, then, rinsed with hot and cold water.

2.2 Natural dyes used for polyester

Natural dyes are dyes or colorants derived from plants, invertebrates, or minerals. The majority of natural dyes are vegetable dyes from plant sources—roots, berries, bark, leaves, and wood—and other organic sources such as fungi and lichens. In general, natural dyes apply on polyester fabric using exhaust dyeing method. The dyeing of polyester is carried out using material: liquor ratio of 1: 15 to 1: 50, temperature above 90 degree and pH ranges from 4-8. The dyeing is carried out for 1to 1.5 hrs.

Z. Motaghi & S. Shahidi [8] have applied madder and weld natural dyes on polyester fiber after plasma sputtering treatment. *Madder* (*Rubia Tinctorum*) is a Eurasian plant. The root of madder produces red dye or pigment. *Reseda Luteola* is a plant of species; source of *weld* natural dye produces bright yellow dye. In dyeing process, the plasma sputtered samples directly were dyed with madder by using exhausted method. It was observed plasma treated fabric dyed with madder showed chemical bond with polyester fabric. The fastness property of fabric improved as compare to unexposed plasma fabric.

Curcumin is extracted from *Curcuma Longa L*. produces yellow colour on the textile material and *Saffron* is a spice derived from the flower of *Crocus Sativus*, commonly known as the *"saffron crocus"*. It makes tone of golden yellow colour. Elnagar *et al* [10] were used *curcumin* and *saffron* natural dyes on polyester fiber in our study. For dyeing procedure the authors were introduced ozone treated pre-mordanted fiber contained by ferrous sulphate into dye bath. The samples showed moderate wash and light fastness. Hasan M. Mahabub *et al* [16] have applied purified *curcumin* on polyester and obtained various shades of yellow colour like brown orange, black orange etc. with different dyeing parameter of pH value, temperature and time. Ethanol, chloroform, acetone and n-hexane are used as solvent to extract the dye from *Curcuma Longla L*. Before applying of exhaust dyeing method polyester fabric were pre-mordanted by aluminium potassium sulphate, copper sulphate and tartaric acid. It was observed that using Copper sulphate as mordant gives better result for colour strength and fastness.

Mohammad A. S. [12] has studied on *Henna* and *onion skin* natural dyes. Henna is obtained from *Lawsonia Inermis* plant which have found red-orange dye molecule. Onion skins are one of the reliable natural dyestuffs found in two different ways - yellow onion skin produces rich golden yellow shades and red onion skin makes earthy range of colours. For application of dyes, author has introduced pre mordant of polyester fabric into dye bath under closed dyeing system. It was observed that onion skin dyed fabric have higher value colour strength relatively to henna dyed fabric.

Kola nut is the fruit of the kola tree belongs to the family of *Sterculiaceae*. Ado A. *et al* [13] have applied kola nut dyes on polyester fabric in three varieties – red, white and bitter. Author has extracted dye through kola powder soaked by distilled water. Myrobolan and Metal salts used as a Mordant applied in three stages – pre, simultaneous and post. After that mordant wetted fabric entered into the dye bath. Authors have found fastness property to be good in simultaneous mordanting method.

Kundal *et al* [14] have worked on *Ficus cunia.* It is a species of plant belongs to the family Moraceae produces light brown shade applied on mordant polyester fabric. Dye was extracted aqueous dye solution. Fabric was treated with three mordant techniques – pre, simultaneous and post using with Rota Dyeing machine. Dyed fabrics showed improved fastness properties as compare to untreated mordant fabric and obtained large no. of shades using with different mordant and mordanting methods.

M.F. Shahin *et al* [15] have applied *Rhubarb* on polyester fabric treated with alkali NaOH at L.R. 1:50 at different degrees of temperatures (50-80̊ C) for various durations (30-120 min.). Rhubarb is a perennial plant and Dolu dye extracted from this plant, produces shades of bright yellow brown. The author has used exhaust dyeing method. Results shown that alkalis treated fabric produced different shades of colour other than untreated fabric. It is also shown alkalis treated fabric improved fabric properties and performance.

Ratanjot (Arnebia Nobilis) a natural source of red dye has traditionally been used as a food colorant in cosmetic formulations and pharmaceutical preparation. Bairagi and Gulrajani [17] have studied that the *Ratanjot* extract behaves as disperse dyes and affinity for hydrophobic filament such as Nylon and Polyester.

3. Application of Natural Dyeing on Nylon Fabric

Nylon is a polyamide fiber made up of hydrocarbon repeating units joined together by highly polar amide functional groups. The amide groups provide sites for hydrogen bonding to dye molecules. The ability of a dye to bond to a fabric may be improved by using of mordant and steam treatment [18].

3.1 Pre treatment processes used for Nylon fabric

3.1.1 Mordant

Lokhande *et al* [19] have studied various mordants like Aluminium Potassium Sulfate, Copper Sulfate, Ferrous Sulfate, Stannous Chloride, Tannic Acid, Harda Powder were used before dyeing of nylon fiber. In this work pre-mordanting method was used. For mordanting, pots were prepared with the required amount of mordant (on the weight of fabric basis) and fabric was introduced into the pot at room temperature (25 °C). The temperature of the bath was raised to boil and mordanting was continued for 45 min. Ibrahim *et al* [20] have worked on various mordants like alum, Zn-sulfate and tannic acid and applied on polyamide-6 fabrics for natural dyeing. Mordanting was done at 90 °C temperature, 1: 30 LR for 30 minutes duration and then samples were thoroughly rinsed in water and dried at 80 °C/5min.

3.1.2 Steam treatment

Steam treatment is an important part in textile finishing. Presetting of goods make it possible to use higher temperature for setting without considering the sublimation properties of dyes and also has a favorable effect on dyeing behavior and running properties of goods. Rossi *et al* [21] have studied lumber steam treatment on natural dye and investigated wash fastness. Lumber treatment is method of wood preservation.

3.2 Natural dyes used for Nylon Fabrics

Nylon is commonly dyed with chemical dyes. But in recent years, natural dyes considered for dyeing on nylon fiber / fabric. Lokhande *et al* [19] have studied on three natural dyes

Onion *(Allium cepa),* Lac *(Laccifer Lacca)* and Turmeric *(Curcuma longa),* Onion is a good source of colour obtained yellow and earthy colours. Lac extract from the scale insects obtained red dye. Turmeric extracted from rhizomes of turmeric produces bright yellow colour. Authors have applied above these dyes on pre mordant nylon fabric using with Open dye bath and HTHP dyeing. The results have shown that, mordanting of copper and iron are giving slight improvement in the light fastness, while alum and tin brings brighter shades of dyeing. The wash fastnesses with all mordants are quite good

Ibrahim *et al* [20] have applied safflower and madder natural dyes on pre mordant polyamide – 6 through exhaust method in the presence of Albegal® Bleveling agent. The results have shown eco friendly mordants bring remarkable improvement in the colour strength, UV-protection and anti-bacterial property.

Ticiane Rossi *et al* [21] have worked on lumber steam treatment of *Eucalyptus* wood on nylon fiber. They used exhaust dyeing process without addition any mordant / agents. Dye bath contained NaCl at the concentration of 20 g/L. and then investigated wash fastness analysis. The results have shown nylon fabric dyed in brownish shade and excellent washing fastness rating (4.5).

Elnagar *et al* [10] were used *curcumin* and *saffron* natural dyes on Polyamide fabric. For dyeing, authors were introduced ozone treated pre-mordanted fiber contained by ferrous sulphate into dye bath and found as a result moderate wash and light fastness.

Arora A. *et al* [22] have dyed various textile substrates such as cotton, wool, silk, nylon and acrylic with hexane extract of *Ratanjot* using exhaust dyeing method. The dyed polyester shows pink colour, Nylon shows blue and all other substrates acquire purple colour under similar dyeing condition.

4. Application of Natural Dyeing on Acrylic fiber

Acrylic synthetic fiber made from a polymer (polyacrylonitrile), contained about 85% acrylonitrile units. It has good thermal stability and moisture management.

4.1 Pre treatment processes used for Acrylic fabric

The ability of a dye to bond to a fabric may be improved by using of mordant. Guizhen K. [23] has studies on ferros sulphate and cupric sulphate mordants on acrylic fiber before natural dyeing. They used simultaneous mordant method with 1: 100 bath ratio in our orthogonal experiment. El-Shishtawy *et al* [24] have studied on alum and Feross Sulphate on modified acrylic fabric as a mordant. For mordanting they adjusted pH value with acetic acid and then boiled for one hr.

4.2 Natural Dyes used for Acrylic Fabric

Guizhen K. [23] has studied on *Rhizoma coptidis* and its dye-ability in terms of thermodynamic and kinetic properties and dyeing condition on pre mordant Acrylic fiber through iron salt and copper salt. *Rhizoma coptidis* is also known as *coptis chinensis*, belongs to perennial herbaceous plant, produces yellow colour. For dyeing they used orthogonal experiment. The result has shown dyeing temperature is most significant factor, colour value increase with dyeing temperature and wash fastness good in both cases (4-5 grade).

El-Shishtawy *et al* [24] have used both dyes on pre treated modified acrylic material for dyeing with presence of sodium sulphate. Result has shown *Madder* gives good fastness as compared to *Curcumin*. It also shows clearly colour differences in the presence of different mordants.

Purwar. *et al* [25] have worked on application of *Ratanjot* natural dyes on Acrylic Filament. To avoid pre-treatment recently, ratanjot has been added during manufacturing of acrylic fiber as dope dyed material. It was observed the dyed fibers have very good fastness property.

5. Conclusion

So far, less work has been carried out on dyeing of synthetic fiber with natural dyes. Synthetic fabric requires pretreatment process before dyeing with natural dyes. Among pretreatment process majority of the work is carried out on mordant process. The natural dye along with mordant gives good fastness properties. There is need to carry out more research work to improve the fastness properties of natural dye on synthetic fabrics. There is need to develop data base with production of appropriate shade card for synthetic fabrics.

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