Sustainable Natural Dyeing of Garments with Rare Earth Salts

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Abstract

Sustainable Garment dyeing using natural dyes have been attained by augmenting with rare earth salts as mordants replacing the conventional mordants. This could be achieved using different dyeing techniques. Apart from Exhaust dyeing, Foam dyeing and Spray dyeing techniques were attempted. All the garment dyeing techniques yielded even dyeing and good fastness properties.

Keywords

Sustainable natural dyeing, Rare earth salts, Exhaust dyeing, Foam dyeing, Spray dyeing

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1.0 Introduction

Garment dyeing has become an increasingly important part of dyeing industry in the recent years. There has been a significant growth in the demand of Garment dyeing due to rapid fashion response [1,2]. There are several advantages in switching over to garment dyeing. We have attempted to do garment dyeing with natural dyes using different techniques. All of them have yielded excellent results in terms of evenness of natural dyeing and fastness properties of the dyed garments. In our case we have used rare earth salts as mordants with natural dyes.

2. VERSATILITY of Rare Earth salts

Eco-friendly Natural Dyeing of natural fabrics such as Cotton, Silk as well as synthetic fabric like Polyester and semi synthetic fabric viscose using Rare Earths Metal Salts as Mordants by replacing traditional metal mordants signifies its versatility. We have carried out natural dyeing of these fabrics using nonconventional mordant salt. These nonconventional mordant are rare earth salt (RE salt) namely- Cerous sulphate, Lanthanum chloride and Yttrium chloride. It is for the first time that these rare earth salts have been used in the natural dyeing process.

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3. COMPATIBILITY of Rare Earth salts

The high coordination capability of the rare earth metal has been the cause of better dye uptake. Different natural dyes have been demonstrated to show better dyeing results with RE salt as compared to conventional mordants. Even the quantity of rare earth mordant required to get desired results is 1/10th quantity of the conventional mordants, thereby directing towards lesser effluent load. Thus the use of rare earth mordant has good prospects in the Natural dyeing of these fabrics. Natural dyeing of Polyester and viscose fabric is quite challenging. Since the polyester fabric has an inherent hydrophobic character the dye uptake under conventional method is very poor for Natural colorants. Dyeing of cotton and silk fabrics were dyed with 14 natural dyes- namely Indigo, Madder, Rheum, Punica, Lac, Leafy green, Henna, Yeliona, Myrobalan, Red Sandal, Walnut, Eupatorium, Turmeric and Catechu using all the three RE salts mainly to check the dye compatibility with the RE salt and also to demonstrate the improvement in dye uptake by the use of the one RE salt. Each of the natural dye showed unique reactivity towards a particular RE salt as shown in table-1. Figure-1 shows garments dyed by Natural dyes- Indigo, Madder and Yeliona.

Figure-1 Garments dyed by Indigo, Madder, and Yeliona natural dyes

Dyes compatibility with RE salts

SL NO	NATURAL DYES	COMPATIBLE RE SALT
1	MADDER (RUBIA)	YCl_3
2	EUPATORIUM	YCl_3
3	RHEOM EMODI	$Ce_2(SO_4)_3$
4	PUNICA	YCl_3
5	MYROBALAN	YCl_3
6	DRY WALNUT	YCl_3
7	TURMERIC	$LaCl_3$
8	RED SANDAL	YCl_3
9	CATECHU	YCl_3
10	LEAFY GREEN	Ycl_3
11	LAC (NIMBUS)	Y_2O_3
12	HENNA	YCl_3
13	YELIONA	$LaCl_3$

Table 1 Showing dye compatibility with different Rare earth salts

The chelation sites for Curcumin colorant of Turmeric dye and indigo molecule of Natural Indigo dye are shown in figure 2 as (a) and (b).

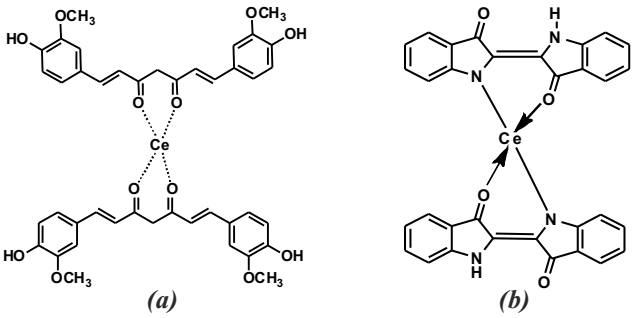

Figure-2 shows chelation of Curcumin molecule (a) and Indigo dye (b) with Cerium ion

4. SUSTAINABILITY with Rare Earth salts

In order to prove the aspect of sustainability of Rare earth salts which have been used as mordants in natural dyeing, the toxic index was evaluated by us. We were interested to find out the traces of RE salts on the fabric as well as on effluents. Cerium salt mordanted with 1 % owf for cotton fabric showed the following results:

Toxic Index study for Rare earth salt mordants

Cotton-dyed fabric treated with Cerium salt (when we used 1 %mordant solution)

- The total digestion method analysed by Method– DIN EN 1671-I is 313.9.mg/kg.
- Perspiration method analysed by Method --DIN EN 16711-II is 0.558 mg/kg.

Dye Effluent analysis showed the following results:

Now we are using only a 0.4 % mordant solution of Rare earth salts

- The total Cerium content in the used mordant solution is 1.09 mg/kg
- The total Yttrium content in the used mordant solution is 0.78 mg/kg

We can definitely use rare earth metal mordants safely during natural dyeing of fabrics and garments. This makes natural dyeing sustainable and safe for both human beings and environment.

4. Sustainable Natural dyeing of Garments

4.1 Exhaust dyeing:

Exhaust natural dyeing of jacket has been carried out using madder dye along with RE salts as shown in figure 1. Exhaust natural dyeing is a method of dyeing a textile material or garment using a natural dye and a mordant. The method involves the gradual transfer of dye from a dye bath to the fabric, the dye molecules move from the dye bath solution to the fibers of the fabric. This is due to its ability to coordinate with the fiber using a metal salt as bridging head between the two. The affinity of a dye can be influenced by chemical additives such as mordants or even by raising the temperature of the dye bath. In our case we have used RE salt as mordant as shown in figure-3.

Figure-3 Exhaust dyeing of the garment using natural dye Madder and RE salt

4.2 Foam Dyeing

Foam dyeing is an advantageous alternative to conventional dyeing methods due to its environmental benefits and mitigating effluent management issues. The primary dyeing element in this process is foam, wherein air is used instead of water to carry the dyeing process. Foam plays a key role in foam dyeing process as they are carrier of the dye molecules. Foams are formed using foaming agents dissolved in water to make aqueous solution which then spreads on the textile material [3] These agents must have the quality to produce foam immediately, they should be temperature resistant having quick wetting and stabilizing effects. Foam can be of two types- dispersion foam or condensation foam. Dispersion foam is prepared by mixing a gas with liquid while condensation foam is producing gas within the liquid either physically by aeration or by the addition of a chemical. Figure-4 shows garment dyed by Yeliona natural dye comprising of Tessu and Marigold flowers.

Figure-4 : Foam dyed garment with Yeliona natural dye

The continuous methods of foam dyeing have the following steps:

a. Foam generation.
b. Foam application to the substrate.
c. Foam distribution with simultaneous drainage and diffusion of the liquid into the substrate Foam collapse and release of active substance.
d. Fixation of the active substance.

Advantages

1. Fixation of dye into fiber can be improved.
2. Diffusion of dye into fiber can be enhanced.
3. Stability of the fiber dyed obtained is high.
4. Outcome is more in short time duration.
5. Waste generation is less and energy saving process.

4.3 Spray Dyeing Technology

In textile wet processing industry water-consumption is the highest industries.20% of global industrial pollution is a result of wet textile effluents. These textile effluents contain a large number of toxic chemicals. Thus, technologists have been working to reduce these water contaminations, by introducing a new technology called Spray dyeing technology. It is fairly new methodology which looks very promising.

Mechanism

This method is a waterless method for dyeing fabric, instead air is used to help the dye molecules to enter into fibers. In this method, Initially the fabric is heated and then the dye is injected from a sprayer directly into the fabric. As a result this technology is advantageous than any other conventional dyeing methods such as vat dyeing, cationic dyeing, etc. The color after dyeing process results in rich look and lasts for a longer period of time [4].

Advantages

- Spray dyeing uses 95% less water and 86% less energy than conventional fabric dyeing processes.
- Only 1% of spray Dyed fabrics are damaged during this process.
- It yield maximum color durability.
- The process does not require any post-treatment or finishing.

The Spray dye process substantially reduces the environmental load of the colored effluent and also improves the fastness performance of the finished fabric. By removing the requirement of water at the point of color application, Spray dye technology is recommended for regions which lack the water resources. It is very well known that traditional processes are energy and water intensive, Spray dye technology is best suited for textile coloration. Slowly Spray dye technology is maturing, and it is expected to find additional benefits from this technology wherein power usage, waterless direct application of dye is easily doable. Spray dye technology thus show apparent benefits over traditional dyeing processes and can be adapted as a new technology for improving the coloration of textiles. Figure-5 shows denim jacket spray dyed by Indigo.

Figure 5 shows a Denim jacket dyed with Indigo through the Spray dyeing method

5. Conclusion:

Garment dyeing with natural dyes using rare earth mordants has given very good results. Exhaust dyeing, Foam dyeing and Spray dyeing techniques were adapted for different natural dyes which yielded in even dyeing despite the fabric construction, sewing thread, buttons, zippers, jacket lining etc., dyeing process and the machine used for dyeing helped us to achieve uniform dyeing and good fastness properties of the dyed garments.

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