Poll Res. 39 (February Suppl. Issue) : S80-S86 (2020)

ISSN 0257–8050

NATURAL DYES: AN EMERGING ECOFRIENDLY SOLUTION FOR TEXTILE INDUSTRIES

KARUNA SINGH[1], PANKAJ KUMAR[1] AND N.V. SINGH[2]

[1,2] Department of Botany, Udai Pratap College, Varanasi, India
[3]Department of Teacher Education, Central University of South Bihar, Gaya, India

(Received 30 October, 2019; accepted 12 November, 2019)

ABSTRACT

Natural dyes are derived from natural sources like plants, animals, minerals and microorganism. Natural dyes are sustainable as they are renewable and biodegradable and also fulfill the huge demand of textile industry. In India, an average mill producing $60x10^4$ m/day of fabrics likely to discharge, approximately 1.5 million L/day of effluent. Excessive use of these synthetic dyes in textile industry may lead to serious health hazards and disturbances in eco-balance of nature. The associated toxicity, carcinogenicity and allergic reactions of the synthetic dyes have raised an interest in natural dyes which are clinically safer, disease free, non-polluting and biodegradable. Present review highlights sources of dyes, classification of dyes, and properties of some common natural dyes.

KEY WORDS: Natural dyes, Sustainable, Renewable, Biodegradable, Hazards.

INTRODUCTION

The textile, leather, paint, and cosmetics industries produce large quantities of wastewater containing dyes that are becoming a major environmental threat. In all these industry, textile industry produces a large amount of dye containing waste water. These effluents containing heavy load of harmful chemicals has contributed to the severe pollution of water, soil and the major polluters of our environment (Gyanendra *et al.*, 2015). Estimated consumption of the textiles globally is around 30 million tonnes for which the expected increase is at the rate of about 3% per annum (Rajendran and Thamarai, 2014). About 70,0000 tones of different dyes are required for the coloration of such a bulk quantity of the textiles (Ogugbue and Sawidis, 2011). Discharge of dye containing wastewater into natural streams and rivers poses serious threat to the aquatic biota, disruption of photosynthesis, food web and in turn causes damage to the aesthetic nature of the water and environment as well. Some of the dyes can cause allergic dermatitis, skin irritation and many types of cancers. There are so many techniques available for removal of dyes like physical, chemical and biological but these methods are costly, energy demanding, generating secondary product and huge amount of sludge. So in this situation natural dyes are among the promising options for developing a greener textile dyeing process.

Natural dyes derived from natural things like plant leaves, wood, bark, stem, seed, root, insect secretion and minerals. Natural dyes exhibit long endurance, beauty and charm. The international rising demand of the natural dyes is about 10,000 tonnes which is merely 1% of the world synthetic dye consumption (Sachan and Kapoor, 2007). Natural dyes are eco-friendly, renewable and also biodegradable, upon degradation; natural dyes do not produce any toxic secondary product. Natural dyes can be used for dyeing of all natural fiber, food additives, medicines, handicraft items and toys, and in leather processing. Many of the dye-yielding plants are used as medicines in various traditional medicinal systems. Textiles produced in Kerala, India by dyeing with herbs as per the traditional Ayurvedic system of medicine and known also as

([1]Research Scholar, [2]Associate Professor, [3]Assistant Professor)
***Corresponding author's email:** Karunasingh50@yahoo.com; lovingmona.singh@gmail.com

medicinal or curative textiles and are being exported to various countries. Various companies are now marketing naturally dyed textiles as health and wellbeing textiles as 'Ayurvastra'.

Ayurvastra clothe is a totally organic, sustainable and biodegradable product. Ayurvastra said as medicinal cloth use for the treatment of diabetes, skin infection, hypertension, asthma and arthritis. Ayurvastra clothe are made of 100% organic cotton or silk, wool, jute, and coir products that has been prepared on handloom processed and dyed by using various herbs to assimilate medicinal properties into them (Saharan and Rani, 2015).

Sources of natural dyes

Natural dyes are derives from natural resources and based upon their source of origin; these are broadly classified as plant, animal, mineral, and microbial dyes although plants are the major sources of natural dyes. There are so many sources for extracting, commons are:

Plants sources

Various parts of plant like roots, flowers, barks, stems, leaves, seeds, fruits are used as source of natural dyes. The blue dye of Indigo derived from the plant *Indigofera tinctoria.* This is very important dye popularly known as the ''king of natural dyes'' has been used from ancient time till now for producing blue color and is today most popular for denim fabric. *Vitex negundo (*Linn.) is a large, aromatic shrub belonging to the verbenaceae family and grows in waste lands and is commonly cultivated as a hedge plant throughout India. The upper surface of the leaves is green and the lower surface is silvery in color. The major flavanoids present in the leaves are luteolin-7-glucoside and casticin. There are so many natural dyes are derives from plant, some common natural dyes are summarized in Table 1.

Animal source

Some dried part of animals is use for coloring agent. Ancient vat dyes were tyrian purple derived from the Mediterranean shell fish of genera *Pura* and *Murex*. This dye produced a very fast deep violet color on fabrics. It was very expensive as thousands of mollusks were needed to get a gram of the dye. Hence it was considered a symbol of royalty and was used to color the clothes of the royal family. Insect secretion is the main sources of natural dye extraction from animal. Cochineal dyes obtained from the insects of the species called *Dactylopius coccus* which is still being used to dye textiles. The dye is obtained from the bodies of female insects that live on cactus (*Opuntia* species). Carminic acid which is coloring matter of cactus has very bright red colour has used as food colour. Some common animal origin dyes are summarized in Table 2.

Mineral sources

Mineral dyes are obtained from an impure earthy ore of iron or ferruginous clay, usually red or yellow. Some natural dyes is present in nature as natural form like cinnabar, red ochre, yellow ochre, raw sienna, malachite, ultramarine blue, azurite, gypsum, talc, charcoal black etc. Red Pigments Cinnabar, Red Ochre, Red lead and Realgar are some of the examples of red pigments originate from minerals (Agarwal and Tiwari, 1989). Red Ochre (Geru) is a natural earth pigment. Red lead (Sindur) is a bright red or orange crystalline or amorphous pigment has been used in Indian paintings in abundance. Yellow Pigments Yellow Ochre (Ram Raj), Raw Sienna, Orpiment and Litharge (Massicot) are classified in yellow pigments due to their yellow color range.

Microbial sources

Some bacteria produce coloured substances as secondary metabolites. *Bacillus, Brevibacterium,*

Table 1. Some common natural dye and their sources

Common name	Botanical name	Part of plant use	Color	Types of fabric	Reference
Madder	*Rubia tinctorum L.,*	Root	Red	Wool	Manian *et al.* 2016.
Mango	*Magnifera indica*	Leaves	Different type of dye shade	Silk	Uddin, 2015.
Pokeweeds or pokebush or poke berry	*Phytolacca Berry*	Fruits	Red	Wool	Liu *et al.,* 2014.
Chinese chaste tree	*Vitex negundo*	Leaves	Gray	Silk	Swami *et al.,* 2016
Whit willow	*Salix alba*	Wood	Brown	Wool	Geelani *et al.,* 2016
Cotton wood	*Populous deltoidas*	Wood	Broen to pink	Coton	Geelani *et al.,* 2016

Table 2. Some common animal origin dyes and their sources

Dye stuff	Species	Colour	Use
Cochineal	*Dactylopius coccus*	Crimson red color	Dying and food colour.
Kermes	*Kermes licis.*	Red	Colorationof animal fibere
Lac	*Kerria lacca*	Deep red	Coloration of animal fibers
Tyrian purple	*Shellfish*	Purpule	Dying
Orchal	*Lichen*	Red and purple	Dying

Flavobacterium, Achromobacter, Pseudomonas, Rhodococcus spp. are some of the pigment-producing bacteria (Joshi *et al.*, 2003). Microbes as a dye source offer an advantage as these can be easily grown on cheap substrates under controlled conditions. The dyeing of nylon with prodigiosin pigment extracted from *Serratia marcescens* was attempted by Vigneswaran *et al.*, 2004. Pigments from the fungus *Monascus purpureus* are used for coloration of some traditional oriental food items. It has been used for fabric coloration also. *Trichoderma* sp. has been used for coloration of silk and wool with excellent washing fastness (Gupta *et al.*, 2003). Orchil dye from lichens was used to create violet and purple shades as a cheap alternative to costly purple dye from molluscs. They have also been used to dye wool to shades of yellow, brown, and reddish brown.

Classification of natural dyes

Classification of natural dyes on the basis of chemical structure is the most appropriate and widely accepted system of classification, because it readily identifies dyes belonging to a particular chemical group which has certain characteristic features. Natural dyes contain a wide range of chemical classes like indigoid, lac, anthraquinones, napthoquinoids, flavones, chlorophyll and ketone.

Lac dye

Lac dye (*laccifer lacca*) is the most ancient dye from animal. Dye extract from a scale insect *laccifer lacca*, found India, South-east Asia, Nepal and China. The deep red color obtained from hard crude shel lac. The lac dye has high light and wash fastness on silk and wool.

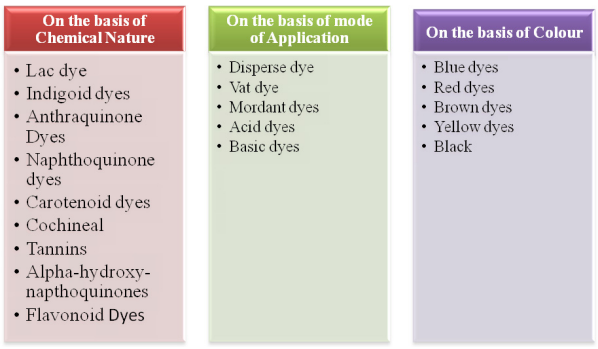

Fig. 1. Classification of natural dyes

Indigoid dyes

This is the most important class of dye. Chemically it is indigo natural blue, found in India, Europe, Japan, Greece, Rome and south-east Asia. Indigoid dye extracted from the leaves of *I. tinctoria, I. errecta and I. sumatrana* etc. It is also the coloring matter of pala indigo (*Wrightia tinctoria*), Assam indigo (*Strobilanthes flaccidifolius*), and woad (*Isatis tinctoria*); the last one was used in Europe for blue color before being replaced by superior indigo from India (Garcia et al; 2004) Indigo is insoluble in water, so it can undergo chemical process to make water soluble dyes. This water-soluble form of indigo is used for dyeing textiles. It has excellent colorfastness properties. It is similar in structure to synthetic indigo (C. I. Vat Blue1, C.I. 73000) but it also contains some amount of red dye Indirubin which imparts a rich reddish tone to the textiles dyed with natural indigo.

Anthraquinone dyes

Anthraquinone dye obtained from the both plant and animal and it is important class of red dyes.

The most famous natural dye in this category is alizarin obtained from European madder (*Rubia tinctorum*). Madder dyes are hydroxyl-anthraquinones which are extracted from the root bark of various Rubiaceae, e.g., from madder root (*Rubiatinctorum*). Other dyes include lac, cochineal, morinda, and Indian madder (*manjishth/manjeet*) among others. Carthamin from safflower (*Carthamus tinctorius*) florets is an old traditional red dye having a benzo-quinone structure. It gives cherry red and pink shades on silk and cotton but fastness properties are not good.

Naphthoquinone dyes

These are natural pigments that are widely

distributed in nature and have important biological properties. Lawsone (2-hydroxy-1,4-naphthquinone) also said as red-orange dye present in the leaves of the henna plant (*Lawsonia inermis*) and water hyacinth (*Eichhornia crassipes*).

Carotenoid dyes

Cartenoids also called tetraterpenoids important groups of natural pigments. These dyes give yellow to red color, obtained from different sources like fruits, vegetables, roots, flowers, egg yolk, algae, yeast etc. Carotenoids are brightly colored natural organic pigments found in the chloroplast and chromoplast nearly all families of plants and some other photosynthetic organisms (Niedzwiedzki et al., 2009). *Bixa orellana, Crocus sativus, Curcuma longa, Nyctanthes arbor-tristis,* and *Cedrela toona, are* some of carotenoids source plants. Only plants, fungi and prokaryotes are able to synthesize carotenoids

Cochineal

Cochineal is obtained from an insect of the same name which feeds on the cactus plant. Chemically cochineal is similar to kermenes. The main coloring component of this dye is carminic acid.

Alpha-hydroxy-napthoquinones

The most prominent member of this class of dyes is lawsone or henna, obtained from *Lawsonia inermis.*

Flavonoid dyes

Most of the yellow natural dyes have a hydroxyl or methoxy substituted flavones structure. Dyes with this chemical constitution are found in a wide variety of natural resources. Weld (*Reseda luteola*) or dyer's rocket was widely used in Europe to produce fast and brilliant colors on wool and silk. Various plant sources of flavonoid dyes are *Reseda luteola* (Weld), *Allium cepa* (Onion), *Artocarpus heterophyllus/ Artocarpus integrifolia* (Jackfruit), *Myrica esculenta* (Kaipha) etc (Khan *et al.,* 2011).

Some common natural dyes

Madder *(Rubia tinctorum)*

Madder is a perennial herb plant of Mediterranean and Central Asia, most commonly used for red dye. Madder contains one of the most complex groups of substance of any dye plant. More than 20 compounds are obtained from the plant. Alizarin, the organic dye found in the madder plant, creates the crimson red. Dyers madder, the main source of true red, also served to obtain pink, orange, purple, gray, brown and the most precious black and brunette shades with high color depth. Numerous papers dealing with various aspects of wool dyeing with madder natural dye have been published in the disclosed literature (Gashti *et al.,* 2013; Kasiri and Safapour, 2014 ; Manian *et al.,* 2016). In addition to coloring properties, it also shows some antimicrobial activity against various pathogenic microbes. It use as insect resistant for carpet beetle (Park *et al.,* 2005; Kalyoncu *et al.,* 2006)

Mango *(Magnifera Indica)*

Mango bark has been reported to be used on silk and cotton materials as a source of natural dyes and a wide range of colors have been produced using different mordants (Win and Swe, 2008). On the

Table 3. Pigments used as naturl dyes

Pigments	Colour	Elements	Use
Cinnabar	Brick red	HgS	Dying
Red Ochre	Yellow to deep orange brown	$Fe_2O_3.nH_2O$	Dying
Red lead (Sindur)	Bright red or crystalline	Pb_3O_4 or 2[PbO] .[PbO2]	Painting
Yellow Ochre (Ram Raj)	Yellow	$(Fe_2O_3.H_2O)$	
Raw sienna	Yellow	$FeO.Mg_O$	Painting
Orpiment(Hartal)	Deep orange-yellow	As_2S_3	Painting
Terre-Verte	Yellow green to greenish grey	Hydrosilicates of Fe, Mg, Al, and K (gluconite and celadenite	Dying
Malachite	Green	$Cu_2(OH)_2CO_3$	Painting
Ultramarine Blue(Lajward)	Blue	Lapis lazuli	Painting
Chalk (White Lime	White	$(CaCO_3)$.	Painting
White lead	White	$(PbCO_3)$	Ingredient in lead painting
Charcoal Black	Black	Carbon	Dying

other hand, the use of acid activated mango leaf powder (MLP) has been reported in another study for the removal of the Rhodamine B (RB) dye from aqueous solution (Khan *et al.,* 2011). Mango leaves have been reported to be used in batik painting technique on silk fabric in comparison with other natural dyes (Klaichoi and Padungtos, 2010).

Arjuna (*Terminalia arjuna)*

Terminalia arjuna commonly known as arjuna, is a medicinal plant. The bark and dried fruits of *Terminalia arjuna* are used for manufacturing the dye. The dry bark from the stem contains 15–24% tannin and is used in tanneries. It also has medicinal quality: its barks acts as anti- dysenteric anti-pyretic, astringent, cardiotonic, lithotriptic, anticoagulant and antimicrobial properties. The major phytoconstituents present in the fruits are hydrolysable tannins, gallic acid, chebulic acid, chebulic ellagitannins, and gallate esters (Pfundstein *et al.,* 2010).

Katha (*Acacia catechu)*

The cutch is used as raw material for manufacturing the dye, which is obtained from the Left over of katha produced from *Acacia catechu*. Katha is used as edible paste in pan preparations. The main coloring component is catechin/flavonoid.

Harda *(Terminalia chebula)*

Terminalia chebula (Myrobalan/Harda) is a medicinal plant commonly known as *Blackchebulic myrobalan* grown in India and South-east Asia (Khan *et al.,* 2005). It is one of the Fruits of *T. chebula* are included in the Indian pharmacopeia under the category astringent. It possesses laxative, diuretic, cardiotonic, and hypoglycemic properties. The major phytoconstituents present in the fruits are hydrolysable tannins, gallic acid, chebulic acid, chebulic ellagitannins, and gallate esters (Pfundstein *et al.,* 2010). *T. Chebula* fruits give natural red and yellow dye. It can be applied in textile industry with or without mordants to get a large number of shades.

Nagalingam *(Couroupita guianensis*)

Couroupita guianensis commonly known as "cannoball tree" belongs to the family *Lecythidaceae* is a deciduous tropical tree 75′ tall. It possesses antibiotic, antifungal, antiseptic and analgesic qualities. These are 3" to 5" waxy aromatic dark red and pink flower on the trunk through the year. The tree also produces globular brown woody, indehiscent, amphisarcun (double fleshy) fruits of an astonishing size, almost the size of a human head. Natural indigo dye was first time use from Couroupita guianensis fruit by fermentation technique to obtained dye for colouration of textiles (Tayade *et al.,* 2014)

Turmeric (Indian saffron)

Turmeric is a well-known natural dye and contains more than 100 astounding chemical compounds. The dye is extracted from the fresh or dried rhizomes of turmeric. The dye present is chemically curcumin, which is a poly phenol, gives yellow-orange color. Curcuminoids, the group of chemical compounds responsible for the health benefits of turmeric, include cumin, demethoxy-curcumin and bisdemethoxy-curcumine.

It is a substantive dye capable of directly dyeing silk, wool, and cotton. The shade produced is fast to washing but its fastness to light is poor. The natural mordents such as tannin obtained from myrobolan can be used to improve the fastness properties

Advantage of natural dyes

- Natural dyes are eco-friendly, biodegradable and renewable.
- Residual vegetal matter left after extraction of dyes can be used as manure.
- Natural dye is as U.V. protector (Chattopadhyay *et al.,* 2013).
- Natural dyes have antibacterial, laxative, diuretic and antiseptic properties like myrobolon fruits, turmeric, manjishth root, Arjuna (*Terminalia arjuna*) bark, and safflower florets have curative properties and have been used in various traditional medicinal systems.
- Cellulosic textiles treated with natural plant extract have been found to exhibit flame retardant properties (Basak *et al.,* 2012).
- Natural dye possesses healing properties by absorption of medicinal compounds through the skin. So they are skin friendly.

Limitation of natural dyes

- Natural dye takes longer time for dying.
- Shade range of natural dye is limited.
- Cost of dying is high.
- Color fastness properties of natural dyes are a cause of concern.
- Identification and Characterization of natural dyes is also a major concern.

Fig. 2. Schematic diagram of sustainability issues of natural dyes.

Sustainability of natural dyes

Sustainability is a complex multidimensional concept of environment, human health, economy and social impact. Sustainability comprises "the needs of present generation without compromising the ability of future generation". After the first invention of synthetic dyes "Mouve" the use of natural dyes become a thing of past, only about 1% of total natural dyes are used by traditional dyers, enthusiasts, and hobby groups are the main users of natural dyes who at the cottage level. Some small industries are also using natural dyes and there are a number of companies who are manufacturing and selling natural dyes both as finely ground plant material as well as purified extracts. Natural dyes are obtained from mostly plant sources, higher uses of natural dye would lead to planting of more dye bearing plant which leads to higher carbon fixation in the form of biomass synthesis by plants (Saxena and Raja, 2014.) Since they are derived from natural sources they are biodegradable and renewable.

CONCLUSION

Synthetic dyes due to their carcinogenic, non-biodegradable nature and hazardous effects on environment and human health, re-established the needs of natural dyes to human in terms of dyeing and health benefits (Yusuf et al., 2016). Natural dyes are considered as eco-friendly and biodegradable. It also possesses antibiotic, antifungal, antiseptic and analgesic properties. Despite some disadvantage natural dyes is boon to save the environment. Higher use of natural dyes may lead to the planting of more dye-bearing plant materials which would lead to higher carbon fixation. Natural dyes are sustainable option for textile industry at small scale as well as large scale.

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