Journal for Re Attach Therapy and Developmental Diversities
eISSN: 2589-7799
2023 March; 6 (2s): 475-496

Sustainable Living By Understanding Natural Dyes Used For Textile Dyeing And Their Therapeutic Effects

Hitaishi Singh[1*], Jaya Bharti[2]

[1]*Professor, Department of Home Science, ANDNNMM, CSJMU, Kanpur.
[2]Assistant Professor, Department of Psychology, ANDNNMM, CSJMU, Kanpur.

ABSTRACT

Civilizations throughout the world have used various locally available natural sources like fruits, flowers, leaves, bark, wood, roots insects, and minerals for dyestuff to give colour to their textiles. Till 1856 all dyes were solely derived from natural sources but post 1856, the scenario changed completely. People were introduced to the world of synthetic dyes. These new dyes replaced the natural dyes to such a massive extent that by the mid-19th century in almost all parts of the world, most natural dyes became a lost technology. India was also one of the victims of this change. We lost track of several dye-preparing and developing methods and dye sources. Many of them became fast vanishing knowledge. Though synthetic dyes had many immediate benefits in terms of ease of production and application as well as performance and cost efficiency, they came with a huge cost to pay. This cost was paid by the environment, along with the physical and mental well-being and safety of living beings, especially humans, and the issue of sustainability at large. Thus, sustainable living became the new world order for saving the planet and saving lives on the earth in this century. This paper is an attempt to explore the possibilities of sustainable living by understanding different aspects related to natural and synthetic dyes used for textile dyeing, their pros and cons as well as differences, and therapeutic effects of natural dyes that can lead to overall wellbeing and sustainable living. Hence, it can be concluded that natural dyes are the colourants of future directed toward sustainable lifestyles. They have multiple therapeutic functions that can successfully ensure human health, overall safety concerns, and well-being. Several people from a variety of fields and institutions at local, state, country, and global levels are making sincere efforts, but most of these efforts are are very small scale or restricted to laboratories. Collaborative and concerted large-scale efforts made in the right direction are the need of the hour.

Key Words: Natural Dyes, Textile Dyeing, Sustainable Living, Well Being, Therapeutic Effects

INTRODUCTION:

Humans probably started understanding the concept of natural dyeing when they first extracted colour from any natural source. This might have taken place by accident, but once they had a taste of colours, there was no looking back. They used these colourants for making cave paintings, body tattooing, dyeing textiles for their personal use, and further, as food colourants and for therapeutic purpose. In the coming years and centuries, people started discovering more dye sources and mordants to get better, and a variety of colours. The discovery of mauve colourants and, then the introduction of chemical dyes in the 19th century brought a pathbreaking change in the world of dyed fabrics. From the invention of Perkin's Mauve till the publication of the first edition of the 'Colour Index' in 1924, more than 1200 organic synthetic dyes were introduced (Eric Hagan & Jennifer Pouline, 20 March, 2021). Today, around 1,00,000 organic colourants are available commercially that can be utilised in the textile industry (Silveira, et. al., 2009).

However, as every new invention has some positive and some negative effects, so was in the case of synthetic dyes. Though there was consistency in tone of colours with brighter shades, however, they were harmful not only to human skin and health but also to mother nature. Due to easy application, ability to produce the same shades in bulk, easy processing, and cost-effectiveness, large scale use of chemical dyes started. Despite these positives, dyeing fibre, yarn, and fabric with synthetic dye leads to the release of harmful toxic agents in the environment and causes high pollution. Today, the chemical dye industry is one of the most pollution-causing units of the textile industry in the world. These dyes have a detrimental effect. A study conducted on the Tirupur textile industry in Tamil Nādu state of India by M. Usha & M. Nandini, November, (2010), proclaims that the textile industry at Tirupur alone annually consumes nearly 28.8 billion liters of groundwater. The study found that a typical integrated textile mill in Tirupur produces 15 tons of finished cloth every day which releases around 1,500 cubic meters of contaminated liquid effluent per day containing carcinogenic and allergy-triggering chemicals. On a global scale, the problem is extremely perilous.

Out of the total dye-containing wastewater produced the world over, about 80 percent is frequently released untreated, which either goes into waterways or directly for irrigation ensuing harmful impact on human health and various ecosystems (Jiuyang, Lin, Wenyuan Ye, et.al., 26 October, 2023).

Another important aspect to remember is that "In this high-speed technological era, only aesthetic appeal cannot attract the prospective customers (Anupama Mishra, and Sapna Gautam, 17 August, 2020) therefore, some or the other value addition is required. However, interest in natural dyes is also getting momentum because of awareness amongst people for the environmental footprints of synthetic dyes (Anupama Mishra, and Sapna Gautam, 17 August, 2020), and extremely harsh and visible climatic change people are suffering from.

Therefore, world over there is a strong call, voiced for replacing synthetic dyes with natural textile colourants. This probed the researchers to find out the facts and propose workable suggestions to deal with the problem.

OBJECTIVE

The study is structured around the given major objective-
To explore the possibilities of sustainable living by understanding natural dyes used for textile dyeing and their therapeutic effects that can lead to overall well-being.

MATERIAL AND METHODS:

This is an analytical research study. For carrying out the current study, a systematic review method was used. Here in-depth and exhaustive study was carried out based on various secondary research databases such as previous researches, scholarly articles, reports, etc., available on different search engines and research platforms. Not only statistical and experimental information has been utilised but also qualitative analysis of information has been carried out. The paper is focused on providing answers to important research questions related to the world of natural dyes used for dyeing textiles and their related diverse connotations and concepts. These questions go deep into enquiring essential facts on natural dyes. Researchers have tried to probe into the difference between natural dyes and synthetic dyes in all possible ways along with their not much-known contribution towards a sustainable living. Simultaneously, researchers have also attempted to throw light on the scope of natural dyes as well as explained their lesser-known therapeutic, medicinal, and other important properties.

Although many studies have been done in the past on one or, another aspect of natural dyes however, this is a systematic comprehensive review study focused on the conceptual clarity and importance of natural dyes, their benefits, pros and cons, functional properties and reasons for possessing those functional properties including mordants used with them.

What are Natural dyes?
"Natural dyes, as the name suggests, are obtained from diverse sources such as bark, roots, leaves, fruits, and minerals. There are hundreds of such combinations with different naturally occurring mordants yield an even bigger, bewildering range of hues" (Therapeutic Properties of Natural Dyes, Urbania, 2023).

In other words, "All pigments existing organically produced from plants, animals, or naturally-occurring minerals without the involvement of any chemical in the process is termed as natural dye" (Cheynekoh, March 16, 2020).

So, in a nutshell, "Natural dye is defined as any coulouring agent, compound or substance that can be used to colour multiple mediums and are a complex mixture of components derived or extracted from natural substances where sources are plants, animals and minerals".

Therefore, can be said that there is an array of such sources within the category of animal, plant, and mineral dye sources, such as animals, microbes, insects - e.g., cochineal bugs, kermes, lac, algae, etc.; different parts of plants like leaves, roots, bark, fruits, and seeds, a large number of herbs, shrubs, and trees; rocks, mineral ores, and sometimes some specific soils.

What is the Difference between Vegetable Dyes, Herbal Dyes, and Natural Dyes?
Usually, very conveniently two terms -vegetable dyes and natural dye sources are used synonymously but there is a basic difference. "**Vegetable dyes** are obtained only from plant sources" whereas, **"Natural dye** sources could be animals, microbes, sea creatures, insects and even minerals along with different parts of a variety of plants" (Imtiyaz Ahmed Ansari, 25 December, 2023). Likewise, "**Herbal dyes** are those dyes obtained from natural sources but are used to dye a fabric for infusing medicinal, protective and curative properties for therapeutic purpose".

A number of hues including black, yellow, red, green, blue, mauve, orange, and pink can be derived and their tints, shades, and tones can be obtained from varied natural dye sources" (Imtiyaz Ahmed Ansari, 25 December 2023).

What are Synthetic Dyes?
After the accidental discovery of Mauveine, the first synthetic organic dye in 1856 by William Perkin while experimenting with quinine, the world witnessed a sudden shift in the textile industry towards the use of natural dyes. Natural dyes were replaced largely by new, easy to apply, and abundantly available synthetic dyes. Later on in 1871, Wolfe prepared picric acid dye by nitration of indigo blue dye. Since then, there has been an unending range of synthetic dyes that were introduced to the world (Mathur et.al., 2006). Sources of synthetic dyes are chemical classes such as azo, indigoid, oxazine, triphenylmethane, xanthene, and anthraquinone.

So "Chemically derived dyes are called **Synthetic dyes** and often referred to as **'New dyes'** which are, even now, constantly developing to meet changing demands of the market, new technology & dyeing mechanics, new kind of fabrics, and detergents" (Eric Hagan & Jennifer Pouline, 20 March, 2021).

Besides there are continuous and focused efforts on overcoming serious environmental damages posed by them. Today, dyes commonly used in the textile industry, are synthetic dyes mostly derived from two sources-

- Coal tar
- Petroleum-based intermediates

They are marketed in different forms -

- Granules
- Powders
- Paste
- Liquid

Here the concentration of active chemicals may range from 20 percent to 80 percent. The textile industry uses mainly azo dyes to create different shades of dye and colour different fabric materials. But these dyes may contain more than 20 carcinogenic amines listed under 'California's Proposition 65' requiring the state to publish a list of chemicals known to cause cancer, birth defects, and other reproductive harms. It is reported that several azo dyes and their reductively cleaved products or aromatic amines can affect human health by causing allergies and other diseases. (King-Thom Chung, October, 2016).

These carcinogens have been banned in Japan, India, Vietnam, China, and the European Union. In 1993, India passed legislation prohibiting the use of a total of 112 azo-based and benzidine-based dyes. Further, after Germany banned azo dye-containing textiles from India in 1996, The Ministry of Environment and Forest, Govern of India, banned the use of another 70 azo dyes in 1997.

German Act also prohibited azo dye consisting of amins having some evidence of releasing or reductively cleaved even a trace of carcinogens.

What are Mordants?
Another important element used in the process of application of natural dyes is mordants. The term mordant has been derived from the Latin word '*Mordere'* meaning 'to bite' because earlier it was considered that mordant is the element that eats away the surface of fibre so that dye can seep in (B.H. Patel, 2011). It is a dye fixative element that is used to dye textiles by facilitating the bonding of the dyestuff to the fibre. They not only increase dye affinity but, in many cases, produce different colours, yielding bright, brilliant, and pleasing shades and, improving colour fastness to washing perspiration and light.

Some common mordants are alum (aluminium sulphate), aluminium acetate, ferrous sulphate, copper sulphate, and naturally occurring metallic salts such as tin, aluminium, chromium, iron, copper, etc. They can majorly be divided into three categories-

- Metallic Salts or metallic mordants
- Tannins and tannic acid as mordants
- Oils or oil mordants

Natural dyes are either substantive (do not require mordants) dyes or adjective (require mordants) dyes. Here adjective dyes are used to dye only textiles that is mordanted with a metallic salt or addition of metallic salt to the dye bath (Gupta,1990) otherwise when used alone, they yield very poor results with slight colouration (B. H. Patel, 2011). To name few such dyes are cochineal, fustic, madder, and logwood. 'Hence, a majority of natural dyes need a chemical in the form of metallic salts to create an affinity between the fibre and the pigment. The elements that can themselves be fixed on a fibre and also combine dye with the dye stuff' (Harbhajan Singh, Kumar Avnish Bharti, 2014).

"However, tannins are naturally occurring phenolic compounds of higher molecular weight (ranging from 500 to 3000) used often in the dyeing of cellulosic fibers, are not metallic salts and thus are not considered as mordants. They can be in form of excretion in the bark, leaves, fruits, galls, etc., of plants and are important for yellow, brown, grey, and black natural dyes processing to improve the fiber's affinity for different dyes (Raja and Thilagavathi, 2008)". They are found in different forms such as hydrolysable tannins and condensed tannins found mainly in myrobalan fruit, oak bark, pomegranate rind, gall nut, etc., and also from catechin that produces copper red colour on cotton, wool, and silks with superior washing and light fastness. It was first isolated from the tannins 140 years ago.

Another category is oil mordants which are used to produce turkey red colour while processing madder dye using alum as a principal mordant that washes away and has superior fastness and hue. Indigo is an example of this.

"Thus, mordants are the elements that may be toxic as they contain dissolved metals. Therefore, if not handled properly they can not only harm the health of the dyer but also damage the dye performance in the form of colour fastness, colour correctness and health of the consumer (A. K. Samanta, N. Awwad, H.M. Algarni, 2019)". On the contrary, certain other natural mordants such as *bahera*, are less or not at all harmful to humans and nature.

There are several methods to apply mordants on textiles. Depending on the process, the need for the fabric or dyestuff mordanting can be done (See Figure- 1).

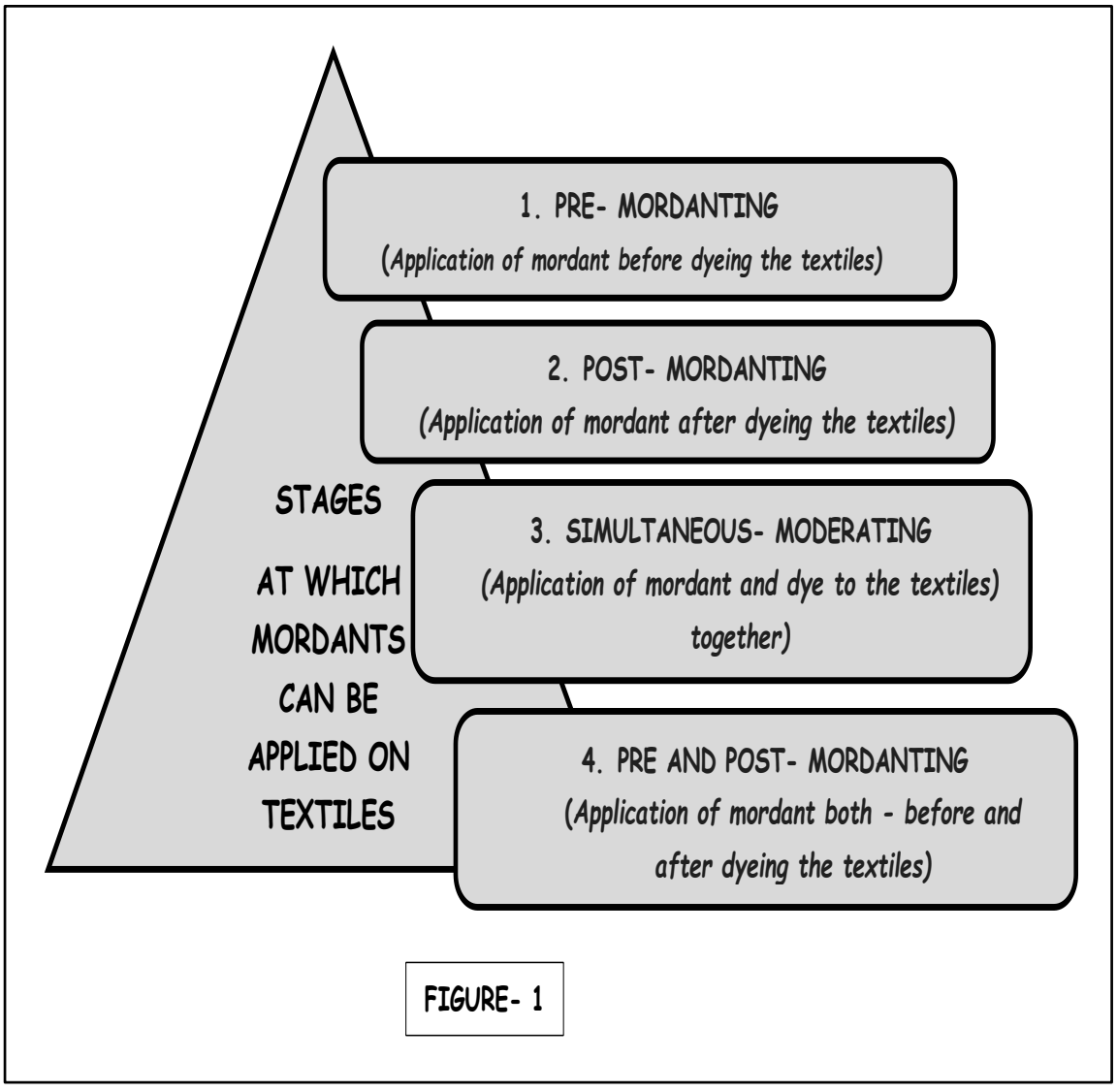

FIGURE- 1

Scope of natural dyes

Though the knowledge of natural dyes and their usage as colourants to dye textile fibre, yarn, or fabric is not a new thing to the world, however, they have far more scope than this. (See fig. 2)
Since the beginning of humanity, animals and plants have been utilized for the development of dyes and pigments (P. Samanta, 2019) capable of colouring diverse materials (P. Samanta, in A.K. Samanta, N. Awwad, H.M. Algarni (Eds.), 2020) such as medicinal or herbal textiles and textile fibres, paper, tannery, leather, food, pharmaceutical products, cosmetics, wood, and, many more. However, Indigo Carmine which is frequently used in food products has a potential health risk and may cause vomiting, diarrhoea, skin irritation, and nausea when ingested.

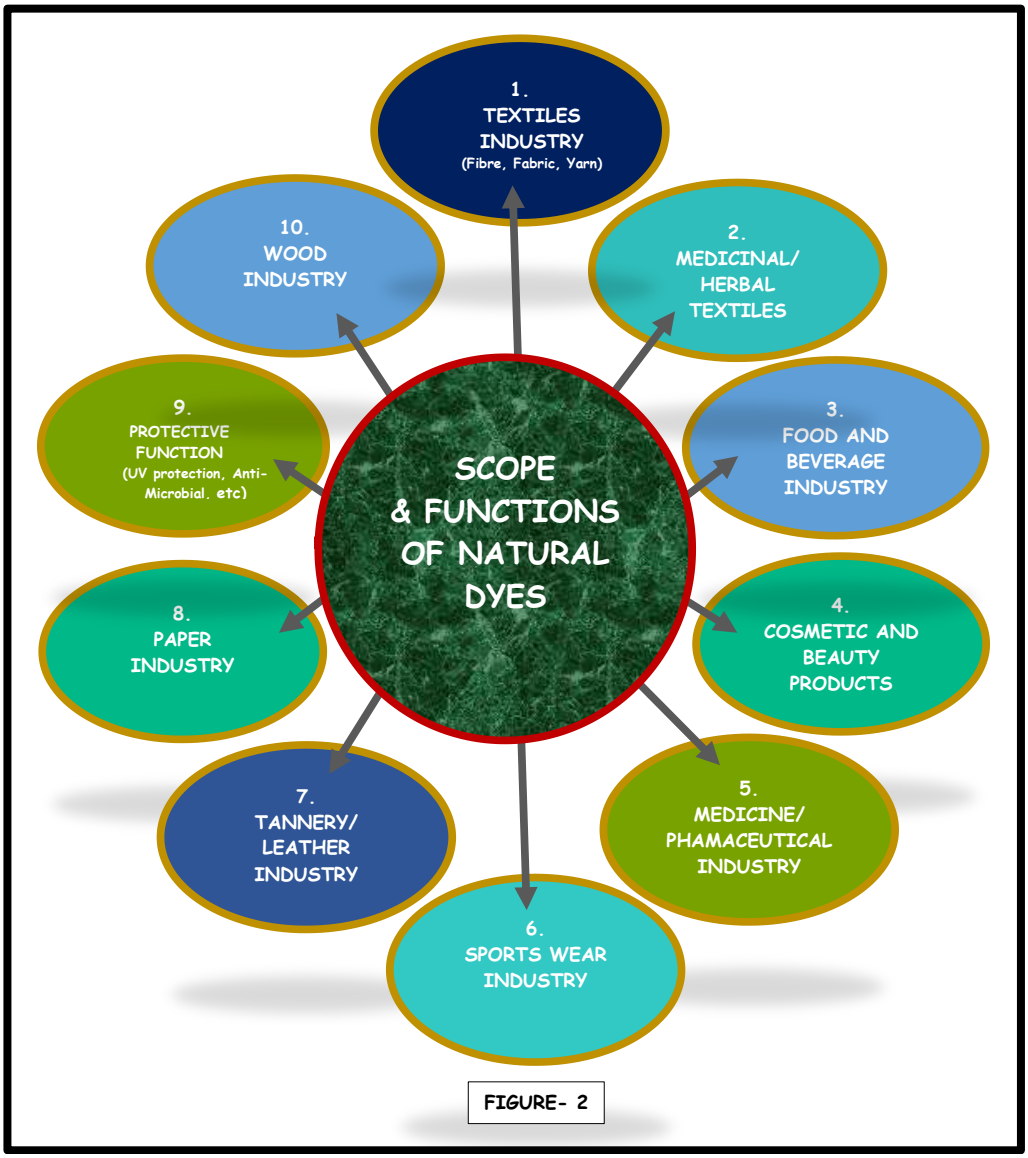

FIGURE- 2

Applications of naturally dyed textiles can be extended to diverse fields such as sportswear and protective textiles due to their various functional properties such as antimicrobial as well as UV protection. Dyes are extensively used in the food industry to add colour, enhance visual appearance, induce aroma, improve taste and texture and also extend the therapeutic properties of food (D.M. Hamdy, A.G. Hassabo, 2021).

Moreover, due to the enforcement of strict environmental regulations and laws on the toxic effect of textile materials dyed with synthetic dye by many countries across the globe, the interest of people in the protection, revival, production, and use of natural dyes has increased.

Why Understanding Natural Dyes and their Importance for Sustainable Living is Imperative:

Cloths dyed with indigo, the first known natural dye used for commercial purposes as colourant, have been found in 4000-year-old mummies as their wraps (Silveira, et. al., 2009). However, between 19th to 20th century, due to fast-paced industrialization, deforestation, urbanization, increasing demand for dyed fabrics, and many other reasons, most natural dye sources and their recipes either languished or reached the verge of extinction. On the other hand, the demand for synthetically produced dye stuff kept on increasing with time. It is projected to increase up to $ 8.7 billion by 2027 in size, at a CAGR (Compound Annual Growth Rate) of 6.5% (Eric Hagan & Jennifer Pouline, 20th March, 2021). According to Fortune Business Insights (13 May, 2024), the global dye and pigment market is projected to grow from $44.68 billion in 2024 to $56.91 billion by 2032, at a CAGR (Compound Annual Growth Rate) of 5.1 over the forecast period.
Today, the textile industry consumes 80 % of the total produced synthetic dyes in the world which generates about 70 billion tons of synthetic dye-containing wastewater annually. Noticeably, India, China, and Bangladesh combined discharge around 3.5 billion tons of textile wastewater each year (University of Bath, 26 October, 2023), which is growing day by day and year by year. Water contamination is augmented by synthetic dyes coupled with water scarcity making wastewater a complex issue (University of Bath, 26 October, 2023).

The most abundant synthetic dyes come from the azo chemical class including other chemical classes such as xanthene, indigoid, anthraquinone, triphenylmethane, oxazine, azine, nitro, etc., that are the main contributors to pollution (Eric Hagan & Jennifer Pouline, 20 March, 2021).
The textile industry uses prohibited Azo dyes and formaldehyde. Chemicals are used not only in dyeing but also to treat textiles for giving several special finishes, such as wrinkle resistance, making it more hard-wearing or less flammable, which leads to severe pollution to the environment. Persistent flame retardant compounds such as bromine used on textiles are another environment-harming content (M. Usha and M. Nandhini, 2010).

Thus, this makes these synthetic dyes used in the textile industry a core environmental concern and a vital sustainability issue worldwide. Though there is the ease of production in terms of quantity and repeating the same shades of colours in any volume along with the application of synthetic dyes, one fundamental fact which has been often overlooked is that the production and consumption of these dyes are extremely toxic and hazardous to the life and living beings on this planet (Eric Hagan & Jennifer Pouline, 20 March, 2021).

It was reported that some of the synthetic dyes contain toxic substances when used and are ingested or come in close contact with the skin, posing risks to human health. Especially their circulatory and ecological footprints are extremely important for the future of the textile industry (KENT, 29 July, 2021) and consequently adversely affecting sustainable living.

Dr. Don Han Soe from KENTECH energy Material and Devices/ Environmental and Climate Technology Track, proclaims, “Dye Containing wastewater is one of the most challenging after effects. Wastewater streams impact lives and the environment in several countries”, despite ease of application of these chemical dyes. Another study by Roya Aghighi (08 June, 2023), stresses that “Though every year textile industry consumes 8,00,000 tons of synthetic dyes, only a fraction of market goes to clothing. Most of it is rendered into dye baths and flushed through industrial sewers into waste tanks or directly into waterways”. “To reduce its toxicity, it is necessary to depolarize the effluent before it gets discharged into the water stream” (Ho & Chiang, 2001). However, due to the high cost and time involved in the process, carelessly a major section of this effluent still makes its way untreated.

Further, water solubility and, the presence of harmful chemicals make it difficult to depolarize. This finally, causes a great challenge for environment managers (Ho & Chiang, 2001), health professionals, dye producers, dyeing unit owners, and consumers. M. Usha & M. Nandini, (November, 2010) raises a serious concern. They say that, “Despite these severe threats to health and ecosystems, there is inadequate infrastructure, investment and insufficient regulatory efforts for making dye usage more sustainable, or for treatment of dye-containing wastewater”.

Major Differences Between Natural Dyes and Synthetic Dyes:
Both natural and synthetic dyes have pros and cons. Before discussing the positive contribution and therapeutic effect of textiles dyed with natural colourants, it is essential to understand the major difference between the two on varied parameters. The major difference between natural dyes and synthetic dyes has been summarized from Table 1.1 to 1.11-

Table- 1 Major Differences Between Natural Dyes and Synthetic Dyes on Varied Parameters

Table- 1.1 Dye Sources, Availability, Sourcing, Quality of Dye Sources, Colour Yield and Use of Mordants

Sl. No.	Natural Dyes	Synthetic Dyes
1.	**Dye sources:** Natural sources	**Dye sources:** Synthetically synthesized chemicals
2.	**Diversity of sources:** • Sourced from a diverse range of sources including vegetable sources such as plant (flowers, fruit, fruit peel and rind, seeds, bark, wood, leaves, roots, etc.), insects such as lac, cochineal, minerals, sea weeds, shells and insects, microbes and other natural elements • Some of the natural dye sources contain more than one dye compound, however various proportions of dyes in natural sources may vary due to different soil types and climatic conditions in which they are grown.	**Diversity of sources:** There are no such diverse sources rather basically petroleum products and coal tar
3.	**Availability of dye sources:** • Collection dye sources depends on natural sources so it is difficult to gather them in large quantities and for some dye sources bulk production, and collection is not possible, so production is in limited quantities • Their availability varies by species, season, and region so production throughout the year is not possible • Mass production of natural dye sources needs large land areas.	**Availability of dye sources:** • Since chemicals can be synthesized in any quantity, so, production is unlimited • Since production is done in factories and laboratories, they can be produced in any colour, in any quantity round the year • Their production requires comparatively lesser land area to set up factories and laboratories
4.	**Inconsistencies in dye quality:** The quality of dye extracted from plants cannot be consistent in terms of colours, quality, and quantity due to differences in several nature- related factors such as type of soil and pH. values, number of rains, and geographical features, topography, unpredictable weather patterns, etc.	**Consistencies in dye quality:** Because it is synthesized in highly controlled conditions, so consistency is assured in terms of colours, quality, and quantity.
5.	**Colour yield:** Poor colour yield	**Colour yield:** Excellent colour yield
6.	**Use of Mordants:** • Various mordants that may be metallic salts, tannins, or oil based mordants to fix a colour or sometimes change a colour to get better results • Mostly metallic natural salts and tannins are used as mordants for making the dyes stick to the fabric as dye fixative which is less or not harmful	**Use of Mordants:** • They do not require the use of mordants as dye fixatives or binders are also chemicals and mostly inbuilt • Synthetic or harmful chemical mordants are used for making the dyes stick to the fabric as dye fixative if required

Table- 1.2 Manufacturing Process and Infrastructure Requirement

Sl. No.	Natural Dyes	Synthetic Dyes
1.	**Manufacturing:** Generally, they have easy manufacturing processes but for a few dyes very complex manufacturing steps are carried out.	**Manufacturing:** This needs careful handling for protection from harmful by-products that may be released or produced during complex chemical processes while manufacturing synthetic dyes
2.	**Dye Extraction Process:** Their dye extraction, purification and application processes such as dyeing conditions, mordanting agents, etc., is extremely complex, labour-intensive, and time taking	**Dye Extraction Process:** • Their dye preparation process follows precise chemical synthesis in laboratories
3.	**Equipments and space:** Requires simple dye house or dye bath in open space with certain containers and other utensils to apply so do not need very large space	**Equipments and space:** Requires full-fledged factory settings e to apply and mostly automatic plants are set up that need more space
4.	**Unique Features:** • In case of certain applications natural dyes could be the preferred choice due to their unique ability to imbue products with their inimitable character and value such as for handicrafts, handloom textiles, bandages	**Unique Features:** • Precise chemical synthesis process employed for manufacturing involved under controlled conditions in industrial plants and laboratories. This results into exact colour production with the right chemical structure and required expected performance to meet diver needs and makes textiles a long-lasting product

Table- 1.3 Processing, Production, and General & Specific Application in Terms of Process, Ease, Labour and Time Incurred

Sl. No.	Natural Dyes	Synthetic Dyes
1.	**Process:** It may range from simple to extremely complex depending on availability and yield of dye source in proportion to demand; and steps incurred in dye making and application process	**Process:** This involves a complex chemical process but once pre-set it becomes quite simple to operate the production and application of dyes
2.	**Dye Preparation:** Difficulty in blending dyes as it takes a long time. It mostly depends on the experience and skill of the dyer	**Dye Preparation:** No difficulty in blending colours as everything is automated
3.	**Skillset required:** Here every step and every type of dye preparation and application requires a specific skill set, knowledge, and experience of the person involved	**Skillset required:** No specific skill set, knowledge, and experience of the person involved are needed for dye preparation and application as they have pre- set standardised formula.
4.	**Time incurred:** Here every step from the collection of dye source to dye extraction and application, is time consuming	**Time incurred:** Takes much less time in terms of production, and application
5.	**Labour incurred:** Highly labour- intensive process	**Labour incurred:** No or very less labour- intensive process because most steps are semi or fully automated
6.	**Standerdisation of processes:** Absence of standardised dye formulation, pre, during and, post-dying procedures, use of mordants, and application process.	**Standerdisation of processes:** They are always standardised in terms of procedures at all the stages and can be applied in the same manner universally.
7.	**Standerdisation of recipes:** • The colour development depends on various elements such as raw materials, mordants, techniques etc., therefore, recipe standardization is difficult. • Very few standardised recipes are available that can be applied universally as raw material vary from place to place	**Standerdisation of recipes:** They have a standard formula of chemicals to be used for making specific dye
8.	**Production Speed (Quantity vs Demand):** The same shades can be rarely produced and one shade can only be produced in limited quantity, thus, unable to fulfill the high demand	**Production Speed (Quantity vs Demand):** The same shades can be produced in unlimited quantities to fulfill the high demand
9.	**Effect of water quality vs application of dye:** Different water quality (soft or hard) also affects the application quality of dye. ***"Natural dyes that are water-insoluble, may produce an uneven or non-uniform colour. (Imtiyaz Ahmed Ansari, 25 December, 2023).***	**Effect of water quality vs application of dye:** They hardly get affected by the quality of water

Table- 1.4 Advantage in Care

Sl. No.	Natural Dyes	Synthetic Dyes
1.	• Fabrics dyed with natural dyes are more delicate and have to be handled with care • They should not be dried directly in sunlight	Fabrics dyed with synthetic dyes do not need any special care as they are extremely colourfast baring a few colours and, easy to wash and handle

Table- 1.5 Colour Consistency, Reproducibility, Durability, Colour Fastness, and Chemical Stability

Sl. No.	Natural Dyes	Synthetic Dyes
1.	**Consistency of colour results:** • Depending on the fabric and from one crop season to another crop season, the colour results can also vary • The reproducibility of the same shades is difficult to control. Many times, the same shades cannot be produced in bulk as dye sources are limited or differ as the topography, and climatic conditions differ along with seasonal variations	**Consistency of colour results:** • They yield precise, consistent, and reliable colour shades which means exact same shades can be produced in bulk • Since these dyes are produced chemically in factories simultaneously making colour variability also possible ***Synthetic textile dyes afford precise control over chemical composition, colour, and performance due to the use of a meticulous chemical synthesis process for making. As a result, synthetic dyes deliver brighter and more enduring colors.*** (***Monica Fting, 21 November, 2023***)
2.	**Colour retention and stability:**	**Colour retention and stability:**

Sl. No.	Natural Dyes	Synthetic Dyes
	These require more care and maintenance to preserve colour stability because, in general, they may not perform well in colour retention	• These do not require extra care and maintenance to preserve colour stability because in general, they perform well in colour retention • They show higher durability of colour, thus, colour is retained after multiple and rigorous use
3.	**Fastness properties:** • Natural dye tends to fade easily and thus, the colour fastness of natural dyes to washing and friction is poor • Their resistance to light and exposure to sunlight is poor as they fade away easily • They may also change their colour slightly when exposed to sweat, and air • The property of transfer of colour on other textiles is also not so good	**Fastness properties:** • Because of excellent stability, if they are well-selected and applied, they are fully colour fast for multiple washes, and frictions • They do not fade to extended exposure to sunlight and do not fade or transfer to textiles with some exceptions of few colours • When exposed to sweat, ally- dyed product may change their colour slightly
4.	**Chemical stability:** • Textile dyed with natural dyes may not withstand acids, bases, and in some cases oxidizing and reducing agents • Show varied levels of stability in various dyeing processes	**Chemical stability:** • Textile dyed with synthetic dyes withstands acids, bases as well as oxidizing and reducing agents • They ensure stability in various dyeing processes

Table- 1.6 Colour Range, Vibrancy, Intensity, Depth, Natural Luster, and Colour Yield

Sl. No.	Natural Dyes	Synthetic Dyes
1.	**Colour range (vividity in colouration):** • A bewildering range of colours can be obtained from hundreds of various natural sources and further, achieving an array of pleasing combinations. • Application of naturally occurring varied mordants can yield even bigger range of hues soothing to eyes ***A wide range of hues and shades using natural dyes is possible (Cheynekoh, March 16, 2020)*** • However, they generally yield softer, and more subtle colours and are unable to match vibrancy of synthetic colours. • Also, they cannot yield a range of colour, shades, and tones in huge quantities, that restrict their use to only high-end-value-added products.	**Colour range (vividity in colouration):** • Since here colours are synthesized chemically, therefore, the production of nearly any colours of choice ranging from as vibrant as primary colours to deep neutral tones can be achieved • They typically offer vibrant and deeper colour due to precise chemical structures making them favoured in fashion and sports ware
2.	**Uniqueness:** • These dyes frequently produce colours with distinctive depths and a natural sheen that gives the dyed fabric a unique texture and visual appeal. • They yield a variety of attractive, smooth, rich, and lustrous tones, and shades which are not possible in synthetic dyes.	**Uniqueness:** No such unique feature is possible here present in natural dyes

Table- 1.7 Eco- Friendliness and Sustainability

Sl. No.	Natural Dyes	Synthetic Dyes
1.	**Sustainability, eco-friendliness and sustainable Development:** • They have green chemistry and are organic in nature because they are derived from natural resources • Natural dyes are fairly less harmful to the environment and are often considered as a sustainable ecofriendly choice leading to sustainability with minimal environmental footprints • Their preparation and application process specifically avoid harmful chemicals and release of toxins, again having low or no adverse environmental bearing • They typically do not produce any such toxic harmful elements as by- products barring a few metallic compounds	**Sustainability, Eco-friendliness and Sustainable Development:** • They are purely synthetic and are inorganic in nature as they are derived from synthetic sources • Since they are synthetically synthesized dyes, thus, they are not considered eco- friendly • Mostly very harmful and toxic chemicals are used as dye sources having an adverse effect on sustainability with hazardous environmental impacts • Their manufacturing and fabric dyeing process involves chemical synthesis and the release of harmful toxic chemicals. They do have a great deal of adverse environmental bearing despite optimization by using some modern processes • As by- products they yield very harmful toxic elements

Sl. No.	Natural Dyes	Synthetic Dyes
	• No threat to future generations as they are environment friendly, sustainable, and promote living hand in hand with nature	• Un-sustainable, therefore, not only harmful to the environment but also a threat to future generations ***The collateral damage of synthetic colouration is to the environment is heavy (Roya Aghighi, 08 June, 2023)***
2.	**Nature (organic/ inorganic), bio-degradability, compostability, and bio-compatibility of waste:** • They are generally organic in nature; therefore, they are decomposable by microorganisms and have high bio-degradability, • They can be composted easily • They are considered bio-compatible colorants so no problem of waste disposal as the waste is also biodegradable or bio-decomposable	**Nature (organic/ inorganic), bio-degradability, compostability, and bio-compatibility of waste:** • They are inorganic in nature; thus, they are generally non-decomposable by microorganisms and have very low or no bio-degradability • They cannot be composted • They are not considered bio-compatible colorants because the waste is non-bio-degradable and non-bio-decomposable causing a severe problem of waste disposal
3.	**Renewability and re-generation ability:** Natural dyes are derived from natural and renewable resources i.e., they can be replaced by new materials obtained from nature or these sources can be regenerated	**Renewability re-generation ability:** They are derived from non-renewable synthetic sources, mostly petroleum products and therefore, non-renewable or cannot be regenerated
4.	**Toxicity level:** • Low, or no baring few, as obtained mostly for natural products • Results into lower human dependence on harmful products and by products	**Toxicity level:** • Very high, as mostly coal-tar and other petrochemicals causes high degree pollution and production of toxic elements. • This results into higher human dependence on harmful products and by-products
5.	**Potential for rebuilding soil health and supporting local communities:** They are an integral part of a regenerative textile movement so support local communities and help in improving soil health	**Potential for rebuilding soil health and supporting local communities:** No support to local community rather pollutes soil and influences human health adversely
6.	**Water pollution and their consequences:** They do not cause water pollution as they generally do not harm the water ecosystem when drained into water bodies. As a result, they do not pose any threat to water ecosystems as well as to humans and other living beings dependent on or consuming products from that water ecosystems.	**Water pollution and their consequences:** Synthetic dyes are mostly petroleum-based which makes it difficult to treat wastewater released out of the dyeing process and causes serious water pollution with alarming consequences. A few of them are quoted below- ***Synthetic dyes end up in oceans and water supplies through toxic runoff and residues from textile manufacturing and dyeing processes (KENT, 29 July, 2021)*** ***Untreated synthetic dyes released into aquatic environments reduce the light available for photosynthesis by primary producers, with consequential impacts on the whole food chain. (Jiuyang Lin, Wenyuan Ye, et al.,26 October, 2023)*** ***Effluent from dye operations is a major source of water pollution. Its ill effects include dying fish species, contamination of soil, and poisoned drinking water. (Roya Aghighi, 08 June, 2023)*** ***Dyes can deposit in fish's gills, lateral lines, or brains, leading to toxicological effects such as uncoordinated movement, respiratory distress, liver damage, and kidney dysfunction. These effects not only reduce the nutritional value of the fish to predators but also lower their reproductive rates (University of Bath, 26 October, 2023)*** ***Further, untreated synthetic dyes can cause coloration of receiving water bodies, hindering the degree of visible light reaching the photic ozone, and have carcinogenic, mutagenic, and teratogenic properties that have toxic impacts on plants, animals, and humans (Jiuyang Lin, Wenyuan Ye, et al.,26 October, 2023)***

Sl. No.	Natural Dyes	Synthetic Dyes
7.	**Utilization of waste materials**: Many agricultural waste materials are used as fuel during the dyeing process and kitchen waste from homes, food, hotel, and catering industries can be used as a dye source.	**Utilization of waste materials**: They are produced in factory settings so no utilization of any kind of waste
8.	**Quantity used and its impact:** Used in lesser quantities in the current textiles industry but has shown potential for application in the future textile dyeing and finishing industry in bulk thus: • Need to take care of water resources in future as more water is required when processing the fabric dyed with natural dyes ***The process of dyeing using natural dyes requires more energy as the dye baths have to be kept very hot for long periods. (Cheynekoh, 16 March, 2020)***	**Quantity used and its impact:** Used in huge quantities in the current textiles industry so proportionately damage is also huge thus, may reduce use gradually and bring it to zero one day

TABLE- 1.8 Functional Properties, Impact on Human Health, Wellbeing and Feel

Sl. No.	Natural Dyes	Synthetic Dyes
1.	The terms 'natural' and 'safe' are not synonymous; there are many naturally occurring substances, e.g., arsenic and asbestos, which are harmful. However, mostly all plant dyes are safe to be worn.	All the textiles dyed with synthetic dyes are by and large harmful in varied degrees. They are highly toxic
2.	**Direct effect on human health:** • The natural origin of these dyes makes them almost harmless, non-toxic with no health hazard • They have therapeutic properties and may act as health cure medium for many diseases and have no carcinogenic effect ***Sometimes mild reaction conditions are involved in their extraction and application (Imtiaz Ahmed Ansari, 25 December, 2023)*** ***Some of the natural dyes have naturally occurring substances that are poisonous such as Hematin and hematoxylin, contained in logwood, a naturally occurring dye, is very poisonous and should not be inhaled or absorbed through the skin (Cheynekoh, March 16, 2020).***	**Direct effect on human health:** • They can be absorbed into the skin and body and cause significant health issues • Instead of curing or having therapeutic properties, they can be eye skin and lung irritants and may cause several skin allergies, skin cancer, lung problems, and respiratory-tract related problems like asthma. ***Their carcinogenic effect is well proven and documented (King-Thom Chung, October, 2016).***
3.	**Direct effect on people involved in dye preparation:** Other than certain dyes that are identified as poisonous, no harmful or toxic effect is found on the persons preparing and producing dyes and also to the surrounding communities of these people	**Direct effect on people involved in dye preparation:** All the dyes can cause harm to those involved in the production process and also to the surrounding communities of these people
4.	**Functional properties:** • **Relaxing and soothing properties:** Natural dyes are soft and relaxing and thus have a very organic feel as they are obtained from nature • ***UV protection:*** *It has enormous functional properties such as higher UV protection to skin* • ***Anti-microbial properties:*** *Naturally dyed fabrics get special properties like anti-bacterial, and anti-microbial* • ***Anti-moth properties:*** *Some of the natural dyes and mordants have anti- moth properties* • ***Non-toxic and hypoallergic properties:*** *They have very little possibility of causing skin allergies as most of them are hypoallergic* ***(Mishra, Anupama, and Sapna Gautam, 17 August, 2020; Pargai, Deepti, Shahnaaz Jahan, and Manisha Gahlot, 11 January, 2020*** • **Deodorizing properties:**	**Functional properties:** **Relaxing and soothing properties:** • Artificial feel, as they have a chemical origin and never have relaxing and soothing properties • No such qualities such as **UV protection, anti-bacterial, anti-microbial, or deodorizing functional properties,** however, these can be induced artificially by adding certain chemical treatments making them all the more harmful

Sl. No.	Natural Dyes	Synthetic Dyes
	Few natural dyes, such as sonchafa (*Mangolia champaca*), and marigold produce natural fragrance in the fabric dyed with it	
5.	Natural dyes are safer in the home environment	Highly toxic so are not safe in the home environment
6.	**Mordants:** Natural mordants for making the dyes stick to the fabric as dye fixative are used. These can be in the form of starch, seaweed, alum (hydrated double sulphate salt), table salt, and vinegar.	**Mordants:** Most do not require any separate mordants. As such mordants do not have any role here.
7.	**Mutagenic Effects:** ***Some studies have shown that few of the natural dye sources may have detectable mutagenic effects e.g., elderberry colour and safflower yellow; others, like carmine, can cause asthma by continuous inhalation (Imtiyaz Ahmed Ansari, Dec., 25, 2023).***	**Mutagenic Effects:** No such effect is there as they are synthetically synthesized
8.	**Unique Feature:** Their multiple functional properties, protective feature, aesthetic quality and, sustainability-oriented nature make them unique	**Unique Feature:** Unique features such as consistency of shades of colours, simple dye preparation methods, easy application, colour fastness, and brightness make them unique

Table- 1.9 Cost-Effectiveness and Market Applications

Sl. No.	Natural Dyes	Synthetic Dyes
1.	They are more expensive than synthetic dye sources due to being limited; difficulty in sourcing raw material; non-availability of dye sources throughout the year; and the complex and time-consuming process of extraction, preparation and application	As compared to natural dyes they are cheaper to formulate, manufacture, and apply, thus, are cost-effective
2.	Incurs high costs so difficult to go for large-scale industrial (mass manufacturing unit of textile dye) production	Since its cost-effective hence, suitable for large-scale industrial (mass manufacturing unit of textile dye) production
3.	Higher cost makes products dyed with natural dyes a high-end market product	Cheaper cost makes products dyed with synthetic dyes as common people market product that can meet bulk market demands

Table- 1.10 Cultural and Historical Value

Sl. No.	Natural Dyes	Synthetic Dyes
1.	Natural dyes hold significant historical and cultural value from diverse cultures of different societies and regions.	As such no cultural or heritage value is involved.
2.	In many traditional art forms and printed, painted, and dyed textiles they are still used extensively reflecting the cultural heritage and traditional knowledge of various regions or societies.	Nowadays, though they are frequently used in traditional handicrafts and printed, painted, and dyed textiles due to their fastness of colour to water, sun and dust, and easy application properties. However, they do not portray any relation with the cultural heritage and traditional knowledge of various regions or societies.
3.	Unique cultural value, product, and design requirements are attached to it that are favoured by high-end market	There is no uniqueness in terms of products, cultural values, or design requirements with very limited or no favour from the high-end market

Journal for Re Attach Therapy and Developmental Diversities
eISSN: 2589-7799
2023 March; 6 (2s): 475-496

Why Natural Dyes and Dyed Products are So Expensive?

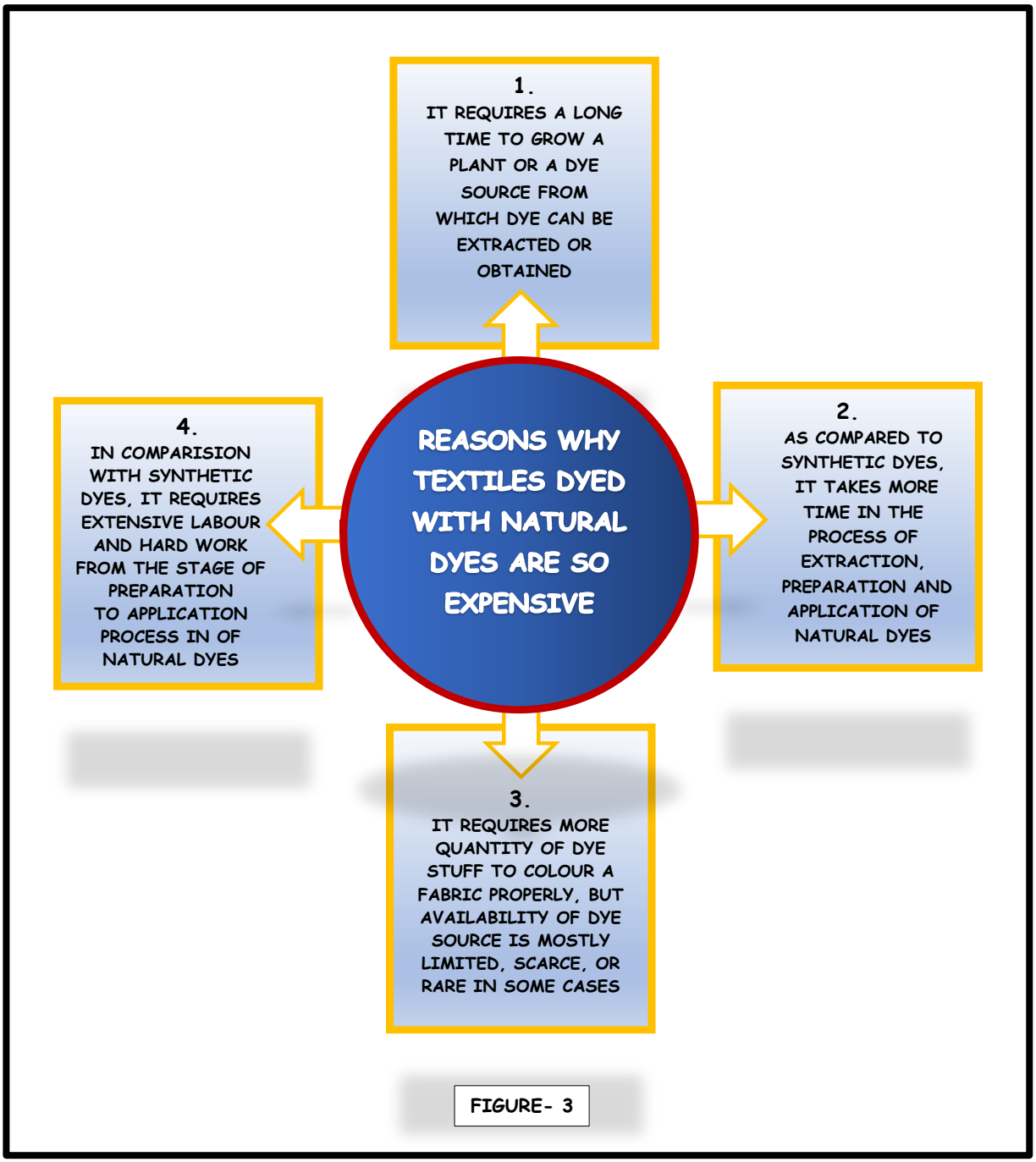

FIGURE- 3

Overall Wellbeing and Therapeutic Effect of Natural dyes

As discussed above, synthetic dyes used in dying textile products have been proven to be highly toxic for human being and environment of the earth. They are causing from simple rashes to skin cancers and many respiratory system-related problems and other diseases.

“It is seen that people who work or live near dye houses using synthetic dyes in developing countries where fast- fashion garments are made, are often diagnosed with rare diseases not seen in other industrial areas or serious skin ailments and rashes (Roya Aghighi, 08 June, 2023)”.

Exploring natural dyes for aesthetics as well as for therapeutic functions leading to overall well-being has been practiced in India since ancient times. Several natural dyes have multiple functional properties and hence they reconnect us with the natural world. They are safer and gentler for the planet and thereby enhance and ensure man's well-being. The demand

for natural dyes which was considerably reduced due to the advent of synthetic dyes, has again been raised by new health-conscious and eco-conscious consumers.

Anupama Mishra, and Sapna Gautam, (17 August, 2020) claims that, "Today, consumers are attracted towards those products that have aesthetic as well as functional properties. Several researches are going on across the globe to increase the existing and explore new functional properties of various natural dyes as they are relevant for the future".

In present times, people are becoming more aware of healthy, hygienic, and safe lifestyles for themselves and their future generations. They are demanding for better products including their clothing with improved functional properties. With the drastic change in climatic conditions, rising temperature, and other adverse weather situations, requirement for protection from UV rays, insects, harmful bacteria, and other microbes, resulting in several vector-borne and other diseases has also been made. Now clothing no longer remains as a basic need or cover modesty, it has also become more functional for protective purposes. Natural dyes, thus, can provide a possible solution as many natural colourants have some inherent attributes other than their colouring property. (See Table 2).

Anti-Microbial/ Bacterial, Antiseptic, Anti-Inflammatory, Anti-Fungal, and UV Protection Functional Properties
These properties can be induced in the fabric when they are dyed using natural dyes. Anti-microbial/ bacterial properties are very important because textile fibres themselves can be affected by the growth of various microorganisms (D. E. A. Boryo, 2013). Out of all, cotton gets affected the most (N. Seventekin, O. Ucarci, 1993).

Since textiles are considered as second skin of the human body and protect the body by covering it and preventing it from coming in direct contact with any outside thing or area, it has to be bacteria and other microbe-free. The sweat of the human body on clothes worn, along with warmth, and oxygen provides a perfect medium and environment for bacterial and other microbial growth. Therefore, dyeing cloth with such natural dye that protects from microbial growth can be a solution to this problem. There are several compounds such as flavonoids, tannins, anthraquinones, etc., present in natural dyes that provide anti-microbial properties to the fabric (M. Yusuf, M. Shabbir, F. Mohammad, 2017).

Textile dyed with certain natural dyes also claimed to provide help in protecting and healing specific diseases. (See Table 2 where only few such examples are presented). When fresh dye of the indigo plant is applied to fabric, it gives relief in the effect of atopic dermatitis (Anonymous, 2019). It was also found that weld plants that yield bright yellow dye and show good dye absorbency, colour fastness to washing, and resistance to light, also have health benefits. They not only have anti-microbial quality but also provide protection against UV rays and keep skin hydrated demonstrating a very positive effect on the skin (P. S. Vankar, D. Shukla, 2018; P. Samanta, 2020).

Table -2 Therapeutic Uses and Effect on Overall Wellbeing of Selected Natural dyes

Name of the Natural Dye/ Mordant Sources	Botanical Name	Responsible Component for Anti-Microbial Properties & UV Protection	Property, Protection from & Status of UV Protection	Other Medicinal Properties	Fabric Dyed	Diseases Claimed to be Cured*
Cutch	*Acacia (catechu)*	Catechin (condensed tannin)	**Anti-microbial/ bacterial** **UV Protection UPF Range** Excellent	• Anti-fungal	• Himalayan Nettle • Cotton	Used for Treatment of Parasitic Infestation & Itching
Harad/ Myrobalan	*Terminalia chebula*	-	**Anti-microbial/ bacterial**	• Controls Cholesterol • Anti-inflammatory • Antiseptic	• Cotton	Controls asthma, anemia & hypertension Cures wounds & ulcers
Indigo	*Indigofera tinctoria*	-	**Anti-microbial/ bacterial**	• Aromatic • Anti-inflammatory • Antiseptic • Anti-allergic • Sterilizing	• Cotton • Silk (Limited amount)	Boosts immunity Controls anemia, cholesterol, & Skin diseases Helps reduce insulin resistance & thus, control diabetes Treatment of effect of atopic dermatitis
Henna	*Lowsinia inermis*	Lowsone	**Anti-microbial/ bacterial**	• Anti-fungal	-	-

Name of the Natural Dye/ Mordant Sources	Botanical Name	Responsible Component for Anti-Microbial Properties & UV Protection	Property, Protection from & Status of UV Protection	Other Medicinal Properties	Fabric Dyed	Diseases Claimed to be Cured*
Indian Madder	*Rubia cordifolia*	Dihydroxy anthraquinones and Trihydroxy anthraquinones Anthraquinones	**Anti-microbial/ bacterial** **UV Protection UPF Range** Very Good	• Stimulant • Sedative, • Anti-inflammatory • Astringent • Antiseptic	• Himalayan Nettle • Cotton • Silk -	Cures various skin diseases Removes blood impurities
Manjistha	*Rubia cordifolia*	-	-	• General medicinal value	• Cotton • Silk	Helps in controlling leprosy It is a blood purifier and diuretic
Eucalyptus	*Flavonoid*	Tannin	**UV Protection UPF Range** Excellent	• Anti-inflammatory • Antiseptic • Muscle relaxant • Stress relieving	• Wool • Cotton	-
Clove	*Syzygium aromaticum*	Eugenol (2-methoxy-4 allyl-phenol	**Anti-microbial/ bacterial**	• Anti-inflammatory • Antiseptic	-	-
Onion	*Allium cepa*	-	**Anti-microbial/ bacterial** **UV Protection UPF Range** Excellent	• Anti-oxidant	• Cotton	Controls diabetes Cures skin diseases
Pomegranate Peels	*Punica crocus and Punica granatum*	Tannins	**Anti-microbial/ bacterial** **UV Protection UPF Range** Excellent	• Astringent • Anti-viral	• Cotton	Controls hypertension Used in anti-microbial treatment
Neem	*Melia azedarach*	Phenolic compounds and Flavonoids	**Anti-microbial**	• Antiseptic		
Jamun Leaves	*Syzygium cumini*	Flavonoids catechin	**UV Protection UPF Range** Excellent		• Cotton	Helps in fighting diabetes
Saffron	*Sativus granatum*	-	-	• Medicinal Value	• Cotton	Controls heart disease
Turmeric	*Curcuma longa*	Curcumin or diferuloylmethane with chemical formula of (1,7-bis(4-hydroxy-3-methoxyphenyle)-1,6-heptadiene-3,5-dione) and curcuminoids	**Anti-microbial/ bacterial**	• Anti-allergic • Antiseptic • Anti-oxidant • Anti-hepatotoxic	• Cotton • Silk	Fights anemia Helps in fighting liver disorders, psoriasis Helps fight skin disease
Banana Peels	*Musa paradisiaca*	Luteolin	**UV Protection UPF Range** Excellent		• Giza cotton	

Sources: Deepti Pargai, Shahnaz Jahan, and Manisha Gahlot, 11 January, 2020; Anupama Mishra and Sapna Gautam, 17 August,2020; Urbania (2023); Santiago Diana, Joana Cunha, Isabel Cabral, (07 November 2023).

For making textiles eco-friendly and more sustainable certain mordants can be used with natural dyes to improve colour fastness as well as add anti-bacterial properties (Diana Santiago, Joana Cunha, Isabel Cabral, 11, November, 2023). These properties can make them an effective alternative to synthetic dyes.

However, Anti-bacterial quality and UV protection are main medicinal properties of certain selected natural dyes and they are healthier alternatives for the textile industry (Diana Santiago, Joana Cunha Isabel Cabral, 11 November,2023).

Moreover, they are well-proven by research evidences. For instance, several non-metallic and anti-microbial finishes exist that may be effective against certain bacteria. According to A. Pal, Y.C. Tripathi, R. Kumar, and L. Upadhyay, (2016), "One such finish is chitosan, which is a deacetylated form of chitin. Chitin is the main component obtained from crustacean shells and it is reported to be effective against both, Gram-positive and Gram-negative bacteria".

Further, some natural plant and insect dyes, such as insect origin 'cochineal (Dactylopius coccus)', and plant origin 'indigo (Indigofera tinctoria), and madder (Rubia tinctorum)' when applied on cotton fabrics, were found to have higher UPF values (Lee Young- Hee, Eun Kyung Hawang, et.al., 2014). Since UV rays have a negative impact on the physiology of all living beings, going a step ahead, Lee Young- Hee, Eun Kyung Hawang, et.al., (2014) proposed that "If certain changes are made in specific parameters of fabric with adequate finishings and UV absorbers, they can be used as Ultra Voilet ray protective fabrics successfully".

Hence antimicrobial finishes should be applied to textiles to destroy or suppress the growth of microorganisms and also to protect the textiles from strength and colour loss, unpleasant odour, and quality deterioration.

Multiple Functions of Microbial Pigments as Dye Source

The microbial pigments or dyes refer to any coloured biological metabolite from which colours can be extracted for dyeing. Usually, no difference is made between pigment and dye, and generally the term 'microbial pigment' is preferred over 'microbial dye' (Richard Fried, Ilinca Opera, Karin Fleck, and Florian Rudroff, 19 November, 2022). Derived from microbial cells these pigments can produce metallic green, blue, indigo, purple, black, grey, brown, cream, yellow, orange, red, pink, etc. They are anti-cancer, anti-inflammatory, anti-microbial, and immunosuppressive (P. Samanta,2020).

Deodorizing Functional Properties

Another property of fabric dyed with natural dye is deodorising effects that has been reported in many studies. Odour in the fabric is caused due to the presence of favourable conditions such as perspiration leading to the growth of bacterial colonies (C. Callewaert, E. D. Maeseneire, et. al., 2014) as discussed above.

In a study done by Y. H. Lee, in 2007 it was reported that fabric dyed with pomegranate rind peel has maximum deodorizing function followed by coffee sludge, casia tora L., and gardenia, respectively. In another study carried out in 2014 on the functional properties of gallnut, it was found that when cotton, silk, and wool natural dyeing is done using gallnut, better deodorizing effect is achieved due to the presence of gallotannin in gallnut. It has displayed bacterial resistance against Staphylococcus aureus and Klebsiella pneumonia, along with providing a better deodorizing property (Y.H. Lee, 2014). The application of fresh dye from the indigo plant acts as a deodorizing or sterilizing compound (Anonymous, 2019). The deodorizing function can also be obtained by dyeing cellulosic and silk fabric with peony, clove, and pomegranate (*Punica granatum*) (Y.H. Lee, H. E. Kyung and K.M. Do,15 January, 2009).

Function as Herbal Textiles

Another term that is frequently used for used for textiles dyed with such natural dye products that have some therapeutic value or functional protective and curative properties is termed 'herbal textiles'. The idea is that when these treated garments and daily utility items come in close contact with the skin, the skin will absorb them and consequently get all the benefits of the natural dye source.

These textiles are becoming popular gradually and are generally used for making undergarments, sleep-wears, towels and bed linens, carpets, coir mats, doormats, etc., (Anupama Mishra, Sapna Gautam, 27 February 2020).

Journal for Re Attach Therapy and Developmental Diversities
eISSN: 2589-7799
2023 March; 6 (2s): 475-496

BOX- 1 (CASE)

Mudapathi Balakrishnan experimenting with dyeing of fabric with herbal dyes
Courtesy: Down to Earth, 2002, https://www.downtoearth.org.in/coverage/textile-therapy-15486

The handloom textile trader hailing from the family of weavers, Mudapathi Balakrishnan from Kinnor, Kerala, when started experimenting with value addition to the textile dyed with herbal colourants, it became a landmark development. He began his experiment during late 20th century just after Germany imposed ban on Indian textiles containing Azo dyes on 1st April, 1996. The ban had come at the time when handloom industry of the country was already going through a severe crisis due to competition by the increased use of power looms. Due to these technological and economic constraints he thought of adding value to handloom cloth and reposition the handloom products as healthy products. He believed that if certain dyes can soak into skin and cause diseases then dyes can in the same way also cure diseases. With the help of her daughter, a student of Ayurved, he started experimenting with common dye yielding medicinal herbs. He got success in getting shades of brown and yellow from *Neem* leaves and turmeric, well-known for their anti- septic properties. Till 2002, Mr. Mudapathi Balakrishnan was able to extract colours from 15 such commonly used herbs used for treating sleep disorders, skin ailments, and breathing difficulties. He extracted red colour from Henna (*Lawsonia inerrmis*), Tree *Turmeric* (*Coscinium fenestratum*) and red sandalwood (*Petrocarpus santalinus*), and scarlet and red from Indian Madder (*Rubia cordifolia*). This way he succeeded in getting a range of fast colours made from decoctions of various medicinal herbs which he used for dyeing cotton fabrics. He confesses that natural dyes are poor substitute of synthetic dyes in terms of colour fastness, range, and tonal variations, however, they have an upper edge in terms of health benefits and sustainability.

Further his experiments were also been supported by the statement of T.S. Murli from Research and Development wing of Kattakkal Vaidyashala, a R&D unit of *Ayurvedic* medicine. He claims that, "The true indigo (*Indigofera tinctoria*) which is known for cotton dyeing has several healthcare applications. Further, another scholar and independent researcher on indigenous science A. Diraruddin affirms that, "Indigo (*Indigofera tinctoria*) is considered to guard the users of dyed fabric with it against asthma, whooping cough, hydrophobia, palpitation and certain other disorders of nervous system, kidney and lungs.

Thus, '*A* bed sheet which is dyed with turmeric when comes in contact to human skin can act as '*Ayurvastra*' that can help in increasing metabolism and get rid of toxins', observes Roya Aghighi (08 June, 2023).

Anti- moth and Mosquito Repellent Functional Properties

Textiles, especially woolen are liable to get damaged due to the presence of moth larvae that usually remain concealed in the fabric, causing great losses. Wool contains protein and due to this, it is estimated that 92.5 pounds of wool fibres are eaten in one year (M. Basuk, J. Behra, March, 2018).

Though very little research has been done on these properties of natural dyes, however, anti-moth functional property is another important aspect that textiles dyed with natural dyes possess due to the presence of 'tannin' in it. It was seen that all the dye sources having anti-moth properties do not contain equal quantities of tannin. In 2015, D.B. Shakyawa, A. S. M. Raja, A. Kumar, and P. K. Pareek claimed that more the amount of tannin a natural dye contains, the more effectively it repels moths. In their study, they observed that onion skin, myrobalan, madder, saffron flower waste, silver oak, clove, wall nut, dholkanali, and yellow roots contain varied quantities of tannin and thus provide different levels of anti-moth properties. Only textiles having about more than 40 percent tannin were found to be effective moth repellent. Silver oak extract contains 47.87 percent tannin whereas the percentage of tannin in pomegranate rind is 45.23 and therefore they function as good anti-moth agents.

Every year millions of people suffer from diseases like malaria, filaria, dengue, chikungunya, etc., caused due to mosquito bites. Global warming is another problem that is leading to mosquito growth and a rise in diseases caused by mosquito bites like malaria, dengue, and yellow fever (E. H. A. Niang, H. Bassene, et.al., 2018)

One of the answers to this problem could be the use of textiles that are dyed with natural dyes. In an experiment, S. A. Rimpi (2017), found that when pomegranate-dyed cotton fabric was treated with polyvinyl alcohol of different concentrations it provided 80 percent mosquito repellency.

Providing Multi- sensory Experience Leading to Overall Wellbeing

Natural dyes, their making process, and application are associated with high-quality multi-sensory effects and experience as during the whole process they reconnect the person with nature, land, seasons and roots.

In other words, the subtle aromatic scent of a few natural dyes, such as marigold, or sonchafa (*Mangolia champaca*), helps in creating multi-sensory effects such as calming effects, stress relieving, soothing, or refreshing effects. It follows the concept of 'Biophilic design' in architecture that aims at bringing nature inside home and thereby reconnecting with nature and finally, enhancing overall well-being.

CONCLUSION AND SUGGESTIONS:

CONCLUSION:

Though the advent of synthetic dyes has brought a paradigm shift in the process of obtaining and producing dyes, dyeing, printing speed, and many other things, their impact on nature and the ecosystems, human life, well-being, and health, was serious and catastrophic. Since they are produced in large quantities, they were able to fulfill mass demand. However, in this process many precious natural dye sources and their processing techniques were lost. The reasons behind this were many, but the important one was that natural dyed fabrics became extremely rare and costly. Also, their demand as compared to synthetically dyed textiles went low as they were not so colour fast, difficult to maintain and scarce in availability.

The current time is viewing the comeback of natural dyes due to the disastrous effects of climate change, the world is witnessing. It is tough to produce them at a large scale but revival of old dye sources and recipes, and experimentation with new options, production has increased and is further increasing every day. This is a good sign. They are eco-friendly, sustainable, and user-friendly. Natural dyes are an excellent alternative to highly pollutant synthetic dyes which are responsible for negative health impacts and degradation of waterways including land and groundwater sources.

There is an immediate need to reduce the dye footprints at every stage from dye source to its application. Collaborative and concerted large-scale efforts made in the right direction may be one option. We have just started thinking big about it and still have a long way to go.

SUGGESTIONS

There are a few suggestions for the change in various processes, for policy, and innovations with regards to the textile dyeing industry that may prove to be useful for the future of the industry, environment, whole living being, and the planet at large. They are as under-

1. Treating wastewater and effluent released from the synthetic dyeing textile industry is a huge problem. Therefore, forming stringent legal norms and their execution should be ensured.

2. New technological innovations regarding developing technologies for treating and re-channelizing wastewater to avoid further contamination of freshwater ways, groundwater sources, and various ecosystems is instantly required. For instance- The researchers from North Carolina State University claim that they have formulated a synthetic polymer that can quickly remove certain dyes from the water and then it can be recovered and reused. (Laura Oleniacz, 11 August, 2022)

3. Another option could be reusing wastewater after treatment for other purposes and thereby avoiding its release in fresh or groundwater.

4. From the green chemistry perspective, there is a strong need for working towards biodegradable dyes.

5. Researches are required to understand the value chain of textile industry vis-a-vis its impact on life cycle process of various ecosystems and consumers of its products.

6. Natural dyes are usually moth-proof and can replace the synthetic dyes in kids' garments. Likewise, some of the herbal constituents are antiallergens and hence are safe for skin contact and are mostly non-hazardous to human beings.

7. Certain medicinal properties present in natural dyes are defining a new range of future textiles i.e., 'herbal textiles' which needs to be researched more. They need to be produced in large quantities and made popular. Herbal clothing, besides colouring, is also known to help fight against many common diseases such as hypertension, skin allergies, asthma, and heart ailments.

8. Natural dyes are usually moth proof and can replace synthetic dyes in kids' garments. Likewise, some of the herbal constituents are antiallergens and hence are safe for skin contact and are mostly nonhazardous to human beings.

9. It is increasingly important to retain the beneficial medicinal attributes of natural dyes in the textiles dyed with them. Hence, refining the processes of extraction, production, and application of natural dyes keeping their medicinal properties intact needs to be done through further R&D in this direction.

10. Though there are a good number of researches on many dye sources and their positive attributes but more work is required on each specific functional property of natural dyes.

11. Those particular natural dyes that are obtained from natural fermentation process could be a potential alternative.

12. Biogenic dyes (microbial pigments obtained from diverse groups of microorganisms as they produce pigments under stress conditions that are biodegradable and non-carcinogenic) can also be a promising alternative to synthetic dyes.

13. To some extent, treatment with natural mordants can infuse antibacterial properties and improve colour fastness in textiles dyed with natural dyes. This way they can be a good alternative of synthetic dyes. Therefore, promoting the use of such mordants can be beneficial.

14. A complete survey of how developments in the textile industry and consumers of its products have been and have affected the environment in the past, needs to be taken up in different pockets of industrial textile clusters and hubs of India.

15. The whole natural dyeing process from cultivation or sourcing of dye raw material to its extraction, preparation, application, finishing, documentation of standardized recipes, and promotion requires expertise from different fields therefore, more collaborative R&D efforts and surveys along with protection and promotional activities are required.

REFERENCES:

1. Aghighi, Roya (08 June, 2023), "We need to talk about the synthetic dyes in our clothes", MaRS, Toronto, Ontario, Canada. Available From: https://www.marsdd.com/news/we-need-to-talk-about-the-synthetic-dyes-in-our-clothes/
2. Anonymous, (2019), "Medicinal Properties of 06 Natural Dyes". Available from: https://nptel.ac.in/courses/116104046/12.pdf

3. Ansari, Imtiaz Ahmed, (25 December, 2023), " Natural dyes, their properties and classification", Medium.Available from: https://medium.com/@imteyazahmadansari6665/natural-dyes-their-properties-and-classification-4b64bb3ddb3d
4. Bashir Hafsa, (19 April, 2023), "Exploring the safety and sustainability of natural dyes in the cosmetic industry, Open Immersive Reader, The Skynth Research Available From: https://www.linkedin.com/pulse/exploring-safety-sustainability-natural-dyes-cosmetic/
5. Basuk, Mayur, and Jagadananda Behera, (03 March, 2018), "A review on woolen cloth's moth and its remedies…", Textile today. Available from: https://www.textiletoday.com.bd/review-woolen-cloths-moth-remedies/
6. Boryo, D. E. A., (2013), "The effect of microbes on textiles material: A review on the way out so far", International Journal of Engineering and Science (IIJES), 2(8):09-13.
7. Callewaert, C., E.D. Maeseneire, et.al., (2014), "Microbial odour profile of polyester and cotton clothes after a fitness session", Applied and Environmental Microbiology, 80(21). DOI:10.1128/AEM.01422-14
8. Cheynekoh, (16 March, 2020), "Natural dyes: Where they come from and their pros and cons", Fabric of the World.https://www.fabricoftheworld.com/post/natural-dyes-where-they-come-from-their-pros-and-cons#:~:text=Hematin%20and%20hematoxlyn%2C%20contained%20in,eyes%20and%20the%20respiratory%20system
9. Chung King- Thom, (September, 2016), "Azo Dyes and Human Health: A review", under Environmental Carcinogenesis and Ecotoxicity Reviews", Journal of Environmental Science and health, Taylor Francis Online, 34(4):233-261. DOI: 10.1080/10590501.2016.1236602 PMID: 27635691 Available from: https://www.tandfonline.com/doi/full/10.1080/10590501.2016.1236602
10. C. Surendranath, (Saturday, 30 November, 2002), "Textile therapy- A handloom trader experiments with traditional medicinal herbs for dyeing garments", Down to Earth. Available From: https://www.downtoearth.org.in/coverage/textile-therapy-15486
11. Fting, Monica, (21 November, 2023), "The way synthetic textile dyes differ from natural textile dyes" Medium. Available From:https://medium.com/@monica-ft/the-way-synthetic-textile-dyes-differ-from-natural-textile-dyes-6d1d9deb976d
12. Fried, Richard, Ilinca Opera, Karin Fleck and Florian Rudroff, (19 November, 2022), "Biogenic colourants in the textile industry-a promising and sustainable alternative to synthetic dyes", Green Chemistry Journal, Issue 1 Available From: https://pubs.rsc.org/en/content/articlelanding/2022/gc/d1gc02968a
13. Gupta, V. K., (2019), "Fundamentals of natural dyes and its application on textile substrates", Chapter in Eedited Volume 'Chemistry and Technology of Natural and Synthetic Dyes and Pigments, by A. K. Samanta, Nasser S. Awwad, H. M. Algarni (Eds.), IntechOpen., pp. 1-124.DOI:10.5772/intechopen.83199 E-Book (PDF) ISBN:978-1-83968-758-7
14. Hagan Eric and Jennifer Poulin, (20 Marth, 2021), "Statistics of early synthetic dye industry", Heritage Science, Springer Nature, 9(1):33. KENT, (29 July, 2021), "Synthetic Dyes vs. Natural Dyes". Available from: https://www.wearkent.com/blogs/news/synthetic-dyes-vs-natural-dyes,
15. Lee Young- Hee, (2007), "Dyeing fastness, and deodorizing properties of cotton, silk, and wool fabrics dyed with coffee sludge (*Coffea arabica L.*) extract", Journal of Applied Polymer Science, Willy online library, 103(1):251-257. Available from: https://onlinelibrary.wiley.com/doi/10.1002/app.25221
16. Lee Young- Hee, Eun Kyung Hawang, Han-Do Kim, (15 January, 2009), "Colorimetric assay and antibacterial activity of cotton, silk, and wool fabrics dyed with peony, pomegranate, clove, Coptis chinensis and gallnut extract materials", under special issue on Functional Colorants in journal 'Materials (Basel)', 2(1):10-21.DOI: 10.3390/ma2010010 **PMCID:** PMC5445691**[Pub Med Central]** Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5445691/ https://www.mdpi.com/1996-1944/2/1/10
17. Lee Young- Hee, Eun Kyung Hawang, et.al., (2014), "Deodorizing function and antibacterial activity of fabrics dyed with Gallnut, (*Galla chinensis*) extract", Textile Research Journal, 85(10):1045-1054.DOI:10.1177/0040517514559580 Available from:https://www.researchgate.net/publication/275245768_Deodorizing_function_and_antibacterial_activity_of_fabrics_dyed_with_gallnut_Galla_Chinensis_extract
18. Lin Jiuyang, Wenyuan Ye, Ming Xie, et.al, (26 October, 2023), "Environmental impacts and remediation of dye-containing wastewater", *Nature Reviews Earth & Environment*, 4(11): 785-803 DOI:10.1038/s43017-023-00489-8
Available From: https://www.nature.com/articles/s43017-023-00489-8
19. M. Hamdy Doaa, Ahmed G. Hassabo, (December, 2021), "Various natural dyes from different sources", Journal of Textile Coloration and Polymer Science, 18(2):2:171-190.DOI:10.21608/jtcps.2021.79786.1066Available from: https://jtcps.journals.ekb.eg/article_185595.html[Scopus] [Google Scholar]
20. Mathur, N., P. Bhatnagar and P. Bakre, (2006), "Assessing mutagenicity of textile dyes from Pali (Rajasthan) using AMES bioassay", Applied Ecology and Environmental Research, Penkala Bt., Budapest, Hungary,4(1):111-118.DOI: doi:10.15666/aeer/0401_111118Available from: https://www.aloki.hu/indvol04_1.htm
21. Mishra, Anupama and Sapna Gautam, (17 August, 2020), "Application of natural dyes for Herbal Textiles", Chapter in 'Chemistry and Technology of Natural and Synthetic Dyes and Pigments', Edited Volume, IntechOpen, pp. 1-124.DOI:10.5772/intechopen.83199E-Book (PDF) ISBN:978-1-83968-758-7 Available From:

https://www.intechopen.com/chapters/73002https://www.researchgate.net/publication/343857415_Application_of_Natural_Dyes_for_Herbal_Textiles

22. Niang, E. H. A., H. Bassene, F. Fenollar, O. Mediannikov, (15 November, 2018), "Control of mosquito-borne diseases: The potential of *Wolbachia*-based interventions in an IVM f\Framework", Journal of Tropical Medicine, 2018(1)/1470459. PMCID: PMC6276417 DOI: 10.1155/2018/1470459 Available from: https://pubmed.ncbi.nlm.nih.gov/30581476/ https://onlinelibrary.wiley.com/doi/10.1155/2018/1470459
23. Oleniacz, Laura, (11 August, 2022), "New method can remove dyes from wastewater", North Carolina State University. Phys.org.Available From: https://phys.org/news/2022-08-method-dyes-wastewater.html
24. Pal, A., Y.C. Tripathi, R. Kumar, and L. Upadhyay, (2016), "Antibacterial efficacy of natural dye from Melia composita leaves and its application in sanitized and protective textiles", Textiles Journal of Pharmacy Research, 10(4):154-159.
25. Patel, B. H., (2011), "Natural dyes", Chapter 11 in Handbook of Textile and Industrial Dyeing: Principles, Processes, and types of dyes, Volume -I, Woodhead Publishing Series in Textiles, pp.-395-421.DOI: https://doi.org/10.1533/9780857093974.2.395Available From: https://www.sciencedirect.com/science/article/abs/pii/B9781845696955500118
26. Pargai, Deepti, Shahnaz Jahan, Manisha Gahlot, (11 January,2020), "Functional Properties of Natural Dyed Textiles" chapter in 'Chemistry and Technology of Natural and Synthetic Dyes and Pigments", by A. K. Samanta, Nasser S. Awwad, H. M. Algarni (Eds.), IntechOpen.in Edited Volume Available From: https://www.intechopen.com/chapters/70792
27. Rather L. J.l, M. Shabbir and A. Haji, (August, 2021), "Sustainable Practices in the Textile Industry" Edited book by Luqman Jameel Rather, Mohd Shabbir and Aminoddin Haji, Scrivener-Willy.DOI:10.1002/9781119818915Available From:https://www.researchgate.net/publication/354038369_Sustainable_Practices_in_the_Textile_Industry
28. Rimpi, S. A., (2017), "Protection and application of natural mosquito repellents cotton fabrics through dyeing", International Journal for Innovative Research in Multidisciplinary Field, 3(8:873-878.
29. Ristea Madalina-Elena, and Otilia Zarnescu, (20 September, 2023), "Indigo carmine: Between necessity and concern", Journal of Xenobiotics,13(3):509-528.DOI: 10.3390/jox13030033 PMCID: PMC10532910 PMID: 37754845 Available From: https://www.mdpi.com/2039-4713/13/3/33 https://www.intechopen.com/books/9203
30. SafeGuardsSoftlines, (06 October, 2023), "India updates Azo dye requirements for imported apparel and textile products" SG 129/12 Available From:https://www.sgs.com/en-be/news/2023/10/safeguards-12923-india-updates-azo-dye-requirements-for-imported-apparel-and-textile-products
31. Samanta, Pubalina., (January, 2020), "A review on application of natural dyes on textile fabrics and its revival strategy" chapter in 'Chemistry and Technology of Natural and Synthetic Dyes and Pigments", by A. K. Samanta, Nasser S. Awwad, H. M. Algarni (Eds.), IntechOpen.in Edited Volume Available From:DOI: 10.5772/intechopen.90038https://www.researchgate.net/publication/338663456_A_Review_on_Application_of_Natural_Dyes_on_Textile_Fabrics_and_Its_Revival_Strategy
32. Samanta, A. K., Nasser S. Awwad, H. M. Algarni, (2020), "Metrics overview", Chapter in Chemistry and Technology of Natural and Synthetic Dyes and Pigments, Edited Volume, IntechOpen, pp. 1-124.m DOI:10.5772/intechopen.83199 E-Book (PDF) ISBN:978-1-83968-758-7
33. Santiago Diana, Joana Cunha, Isabel Cabral, (07 November 2023), "Chromatic and medicinal properties of six natural textile dyes: A review of eucalyptus, weld, madder, annatto, indigo and woad", Heliyon, Elsevier Inc., Philadelphia, USA, 9(11): e22013 DOI: https://doi.org/10.1016/j.heliyon.2023.e22013 Available From: https://www.sciencedirect.com/science/article/pii/S2405844023092216

chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.cell.com/action/showPdf?pii=S2405-8440%2823%2909221-6

34. Seventekin, N., O. Ucarci, (1993), "The damage caused by micro-organisms to cotton fabrics", Journal of Textile Institute, 84(3):304-313.
35. Shakyawa, D.B., A.S.M. Raja, A. Kumar, P.K. Pareek, (2015), "Anti- moth finishing treatment for woolens using tannin containing natural dyes", Indian Journal of Fibre and Textile Research, 40:200-202.
36. Sharma, Sanjay K., (06 March 2015), "Green chemistry for dyes removal from wastewater: research trends and applications" book edited by Sanjay K. Sharma, Scrivener Publishing LLC.Available From:https://onlinelibrary.wiley.com/doi/book/10.1002/9781118721001
37. Silveira, Edgar. P. P. Marques, S. S. Silva, and J. L. Lima-Filho, (March 2009), "Selection of Pseudomonas for Industrial textile dyes decolourization", International Biodeterioration and Biodegradation, 63(2):230-235.DOI: 10.1016/j.ibiod.2008.09.007
38. Singh Harbhajan, Kumar Avnish Bharti, (2014), "Hand book of natural dyes and pigments", Book published by Woodhead Publishing India PVT. LTD. DOI: https://doi.org/10.1016/C2014-0-02803- 1Available From:https://www.sciencedirect.com/book/9789380308548/handbook-of-natural-dyes-and-pigments#book-info

39. URBANIA, (2023), "Therapeutic Properties of Natural dyes". Available From:https://urbania.in/index.php?route=information/information&information_id=26
40. The University of Bath, (26 October, 2023), "Do or dye: Synthetic colours in wastewater pose a threat to food chains worldwide", Editors' notes, University of Bath, Phys.org.Available From:https://phys.org/news/2023-10-dye-synthetic-wastewater-pose-threat.html#:~:text=Water%20contamination%20is%20aggravated%20by,environmental%20and%20sustainable%20development%20issue.
41. Usha, M. & M. Nandhini, (November, 2010), "An Overview about the usage of dyes in the textile industry", in FIBRE2 FASHION and originally published in Textile Review.Available From:https://www.fibre2fashion.com/industry-article/5291/an-overview-about-usage-of-dyes-in-textile-industry
42. Vankar, Padma S., Dhara Shukla, (March, 2018), "Spectrum of colours from Luteola and other natural yellow dyes", Journal of Textile Engineering and Fashion technology, MedCrave 4(2)DOI: 10.15406/jteft.2018.04.00127 Available From: https://medcraveonline.com/JTEFT/spectrum-of-colors-from-reseda-luteola-and-other-natural-yellow-dyes.html
43. Yusuf, M., Shabbir M., Mohammad F., (16January, 2017), "Natural colourants: Historical, processing and sustainable prospects", Natural Products and Bioprospecting,7(1):123-145. DOI: 0.1007/s13659-017-0119-9. Epub2017Jan16----------