

Restricting Indoor Pollution through Organic Wool - Futuristic Sustainable Interiors

Seema Chaudhary^{1*}†

¹*Fashion and Textile Department,
Pearl Academy, New Delhi, Bharat (India).*

*ORCID:

†Corresponding author: seema.singh@pearlacademy.com



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Abstract

Background: Home textiles today are a significant source of indoor air pollution. Chemicals such as formaldehyde, benzene, and volatile organic compounds (VOCs), commonly emitted from synthetic materials and finishes, contribute to poor air quality and pose health risks.

Purpose: This paper highlights the hazards associated with synthetic fabrics and finishing processes in the home textile sector. It also seeks to propose sustainable alternatives that are both eco-friendly and culturally rooted.

Methods: The study explores the traditional use of indigenous organic wool by the Gaddi tribe, a semi-nomadic community from the Himalayan region. Through design experimentation involving natural dyes and modern weaves, the potential of this wool in the commercial home textile market is examined.

Results: The organic wool produced by the Gaddi community, using traditional spinning methods like the charkha and drop spindle, offers a viable alternative to synthetic textiles. The natural wool colors—black, ecru, and blended grey—are both aesthetic and sustainable. The use of this wool not only promotes better air quality but also supports rural livelihoods.

Conclusions: Gaddi wool-based home textiles present a promising solution to reduce indoor pollution while generating employment for tribal women. Reviving these indigenous practices aligns with sustainable development goals and enriches the rural economy.

Keywords: Indoor pollution, home textiles, Gaddi sheep wool, natural dyes

1. Introduction

Humans in today's world are becoming increasingly consumerist. In every aspect of life we are consuming more and more machine-made/factory-produced goods, ranging from personal clothing and food for our daily subsistence to creating our immediate built environments. Exigencies of Commerce as well as increasing life spans, better health-care and reduced mortality rates have all led to extraordinary demands for rapid construction to house our growing populations. All this leads to pressure on the Construction and the Interior Design industries which further impacts our environment and Nature. This situation needs a lot of thinking, and strategies need to be developed to counter such pressures on and safeguard an already fragile Eco-system. This study looks towards the interiors of our built environments, specifically one aspect that is the use of textiles in interiors, and examine the possible role that textiles can play in reducing indoor pollution by using a sustainable material like Natural wool. Apart from secondary research, the Authors have also conducted field visits to gain a better understanding of the traditional practices and processes of wool production and weaving as practiced traditionally by the Gaddi tribe, a pastoral people from Himachal Pradesh in India. The authors have also explored the materials themselves practically, and tried to create design solutions that can be utilized to produce textiles that can suit contemporary Interior tastes.

Sustainable interior design aims at integrating all systems and materials in order to minimize negative impacts on the environment and the users of the space, and maximizing positive impacts on the environment, and the economic and social systems. Sustainable interiors practices and design can lead to the creation of a healthy and clean environment for the users. Such interiors can be created by:

- I -Including/considering sustainable materials and products in the interiors.
- II -Improving indoor air quality by using sustainable products and materials, which results in increased productivity and improved general health and well-being of the users.
- III -Enhancing resource efficiency through efforts to Reduce, Repair, Reuse, and Recycle.
- IV -Utilizing traditional crafts/techniques and vernacular practices, by employing and involving the traditional artisans and craftsmen.

This leads to improvement of life in the built environment along with substantial cost savings from conservation of

energy and resources.

“The Environmental Protection Agency (EPA) believes that sustainability is about achieving the balance of three principles: environmental sustainability, economic sustainability, and social sustainability” [1].

The Definition by The Global Development Research Centre (GDRC) [2] says *“maintaining a delicate balance between the human need to improve lifestyles and feeling of well-being on one hand, and preserving natural resources and ecosystems, on which we and future generations depend”*.

In order to create Sustainable interiors, a designer must try to integrate the building structure, finishes, furnishings, lighting, equipment and other systems that are important in Interiors in such a manner that these components work in tandem. Several theories and viewpoints for Sustainable models for the Economy have been propounded over the years, and one of the more recent ones is the Circular Economy (CE). This is a more holistic approach towards Sustainability and moves away from the earlier theory called the Linear Model. As opposed to the Linear Model, where the credo is “Cradle to Grave”, the Circular Economy approach talks about “Cradle to Cradle”. The CE model suggests changes in the production process and aims to reduce the use of resources. This Model can work well for built environments/interiors if the selection and application of materials used is done judiciously.

In this paper we are focusing on textiles, specifically Natural Wool as a Sustainable material to be used in Interiors for creating pollution-free interior spaces and removing Indoor pollution.

2. Textiles in Interior Environment

Since the dawn of civilization, humans have used textiles in their habitats, and even today, textiles are one of the most widely used materials in interiors of buildings be it residential, commercial, hospitality or institutional.

Textiles are used to create and enhance the look and feel in an interior environment. Varied textiles can be used to create an ambience that can range from light and soft, to rough and rugged, and can create sophisticated and sleek look. Appropriately chosen textiles can also range from simple and spartan to lavish and ornate [3].

Textiles help to personalize any interior space, by adding colour, softness, curvature and flexibility to the built environment. Even a most rigid-looking building can be visibly softened by employing textiles to give a flexible aspect. An otherwise bland space can be modified into a more interesting and vibrant one with the help of appropriate textiles.

Among the most common interior uses for textiles are carpeting, upholstery, furnishings, wall and floor coverings etc.

As textiles are such an integral component of Interior Design, using Sustainable materials (textiles) can help towards creating Sustainable interiors. When it comes to Sustainable Interior Design, textiles play a very important role in creating sustainable interior environments.

Textiles in Interior Design are used for several reasons:

- I Textiles provide protection from sun and rain (used as curtains and blinds). Owing to the built character of the textile (woven, knitted etc.) it also allows certain amount of sun and light to penetrate which illuminates the interior space with daylight.
- II They can be used as insulation material against heat or noise.
- III Interior constructions using textiles look light and also translucent.
- IV Textiles provide interiors with a sense of softness. They absorb sound, and they can improve aesthetics

As the use of textiles in Interiors has been very widespread, there is also the possibility of these textiles to adversely affect the Indoor Air Quality (IAQ) due to the use of chemicals in the production, treatments, and maintenance of these textiles [4]. Exposure to various chemicals found within the environment may trigger symptoms of an illness called Multiple Chemical Sensitivity (MCS). The major cause of this illness is poor Indoor Air Quality.

“Indoor Air Quality (IAQ) is a term referring to the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants.” - Environmental Protection Agency [5]. As many people spend a larger chunk of their time indoors, hence the issue of IAQ can be a major factor to consider while designing sustainable interiors.

3. Indoor Air Pollution: Causes and Effects

The term ‘Indoor Air Pollution’ refers to the presence of harmful contaminants in Indoor air. These contaminants can be of a physical, biological or chemical nature, and this indoor air pollution is directly related to the usage of materials in Interiors. It has been found that generally in some buildings, the Indoor air is more polluted than the surrounding outdoor air due to the presence of materials used in such buildings.

Indoor air pollution can lead to several health problems like Asthma, Carbon Monoxide poisoning, headaches, nausea, eye irritations, depression etc.

Some of the common indoor contaminants are Formaldehyde, Nylon, Carbon Monoxide, Asbestos, Lead etc. and a majority of such contaminants are present in the textiles which are used in Interiors.

Formaldehyde: One of the most commonly used chemicals in the textile industry, Formaldehyde is reportedly a primary source of emission from textiles. Some carpets and textile fabric finishes also contain Formaldehyde. It is also present in glues and adhesives in carpets and draperies.

Released as a colourless gas in the air, Formaldehyde is an irritant that affects the eyes, the mucous membrane and the skin, and can also cause coughing, runny nose, irritation and infection of the sinuses, headaches, fatigue, depression and can also lead to Cancer.

Naphthalene: Commonly used in interiors as a fumigant for controlling moths and as a de-odorizer for wardrobes and washrooms, Naphthalene is also very commonly found in many building materials and Interior finishes materials like poly-vinyl flooring, carpets, plywood, laminates and commercial board, plastic furniture, surface finishes like paints, primers, coatings and adhesives. Naphthalene can also be found in many house-hold cleaning products.

Effects of exposure to Naphthalene can cause hemolytic anemia, damage to the Liver and the Central Nervous System (CNS). Sustained exposure to Naphthalene can also cause cataracts and retinal damage, and it has been found to be carcinogenic.

Nylon: One of the most commonly used material in carpeting, Nylon is a by-product of the refining process of Petroleum, which is a non-renewable resource. The manufacturing process emits pollutants in the air as well as water. Apart from air pollution, nylon can also pollute both the soil and water.

Nylon is not bio-degradable, and discarded nylon carpeting is dumped in the landfills, where it remains for eternity. The other chemical materials along with Nylon in such carpets like sealants, adhesives, are also harmful to the environment, as they can leach into the surrounding soil. Other sources of pollution from carpets could be installation residues, i.e. the products used for cleaning these carpets.

VOCs: Volatile Organic Compounds (VOC) are variety of chemicals, which are volatile in nature and emitted into the environment. Most of these chemicals have been found to have short and long-term adverse health effects (Environmental Protection Agency).

Exposure to VOCs can pose health risks, and present with symptoms and illnesses like eye irritation, respiratory problems. These VOCs can be carcinogenic and are also a

major contributing cause of Sick Building Syndrome (SBS). Some common VOCs that are emitted are Formaldehyde, Sulphur-Dioxide and Nitrogen-Dioxide, from building materials, fixtures, furnishings and cleaning supplies [6]. VOCs are emitted by a wide variety of interior products and materials like paint and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings and office equipment.” - Environmental Protection Agency [5].

In Interior spaces, usage of adhesive in laying the carpets can be a major source of indoor pollution. Carpet adhesives emit high quantity of Volatile Organic Compounds (VOC's) that are harmful for our health and well-being.

Combating Indoor Air Pollution:

As seen above, there are several sources of Indoor air pollution, and there are many techniques and even appliances that can help tackle such issues. However, for the purposes of our study, we are concentrating upon using Natural Wool as a method for reducing Indoor Air pollution. These days, Passive Removal Materials (PRM) are being used in interior environments to cleanse the building of toxic chemicals and VOCs.

The PRM must be energy-efficient, work for longer time frames, must be non-reactive and should be able to be used in an easy manner in an interior environment while covering large surfaces and must also maintain aesthetical appeal. These PRMs are used for reducing occupant exposure to indoor air pollutants [7]. Natural wool fiber in its untreated true form has been considered recently as a Passive Removal Material (PRM) for its ability in removing Formaldehyde, Nitrogen Dioxide and Sulphur Dioxide.

Organic Wool

Wool is a Natural Fiber from the coat of the sheep, which grows naturally and does not require any sort of chemicals or manufacturing to produce. Natural wool is a rapidly renewable resource as the sheep are sheared annually. As per USGB a 'Rapidly Renewable Resource' must be planted and harvested in less than a ten year cycle.

Definition of Organic Wool: Organic wool is that form of wool in which the sheep (the source of the wool) have not been exposed to chemicals like pesticides and are kept in humane and good farm conditions. Such livestock is allowed to roam free, and graze on forage sourced naturally. All the processes involved with wool, from processing of raw wool to scouring, descaling etc. do not use any

chemicals and sustainable processes are followed. As per Global Organic Textile Standards (GOTS) the organic wool must be produced in accordance with federal standards for organic livestock production, which are:

- I Feed and forage used for the sheep from the last third of gestation must be certified organic.
- II Synthetic hormones and genetic engineering of the sheep is prohibited.
- III Use of synthetic pesticides on pastureland is prohibited and the sheep cannot be treated with parasiticides, which can be toxic to both the sheep and the people exposed to them.
- IV Good cultural and management practices of livestock must be used.

Properties of Organic Wool and its Use

- i *Water-absorption:* The inner cortex of a wool fiber is Hydrophilic i.e. highly water absorbent and can absorb up to 30% of its weight in moisture, with a moisture regain figure of 16-18%. Wool fibers absorb and release moisture from surrounding air without compromising its thermal efficiency.
- ii *Wicking:* Wool has a unique property that allows its fibers to absorb water vapor from the air in a regulating sense; absorbing when there is excess moisture and releasing the gained moisture when the humidity level decreases in the surrounding atmosphere. This aids in passive humidity control in an indoor environment, and stabilizing the comfort level
- iii *Density:* Natural, untreated wool is a dense material that can be used for acoustical control in areas such as conference rooms, meeting rooms, lobbies and restaurants.
- iv *Flame resistance:* Wool is naturally flame resistant and self-extinguishes. The fiber will smolder and char, but will not burst into flames. It has a very low flame spread, heat of combustion and does not melt or drip when heated.
- v *Elasticity:* Wool fibers can be bent over 30,000 times without danger of breaking or damage. It is the natural elasticity and wave or crimp that allows this fiber to be stretched as much as 130% and spring back into place when dry; a wet fiber can stretch up to 1/2.

- vi *Thermal Insulation:* As a building insulation material, wool has an R-value of 3.5/inch of thickness.
- vii Wool has the ability to regulate the humidity of an interior due to the matrix inside the cortical Cell. The matrix consists of high sulfur proteins that cause the sulfur atoms to attract and absorb water molecules.
- viii Wool has endless applications that range from industrial to building materials, apparel and home furnishings.
- ix It can be processed as a woven or non-woven, or knitted textile.
- x *Felting Ability:* Because of The scaly and coarse nature of the wool fibers, it allows to felt together and join to other wool or natural fibers with agitation, water and soap.

With the consideration of these properties, wool has the capability to improve the indoor environment quality (IEQ) and the health of occupants through the absorption of indoor air pollutants, humidity regulation and acoustic control. The structure of the wool fiber itself has many properties which makes it a Passive removal material (PRM). We can say that wool, and specifically chemically untreated wool has the capability to improve the indoor environment quality (IEQ) and the health of the users of the interior space by absorbing the indoor air pollutants, regulating the humidity content and through acoustical control.

In this paper we are talking about the Natural wool sourced locally from the pastoral Gaddi tribes, residing in Himachal Pradesh in India. This Gaddi wool, used as a basis for a sustainable IEQ intervention, can be applied to Interior projects.

Gaddi Wool

Gaddis are a semi-nomadic pastoral tribe, found predominantly in from the Chamba District of the Northern Indian states of Himachal Pradesh and Jammu & Kashmir, with some populations in the Uttarakhand state. They rear an indigenous breed of sheep called the “Himalayan White” or “Gaddi sheep” and this breed is the source of wool used by the Gaddis in their clothing and domestic textiles. The “Gaddi wool” is special in many ways:

- i The wool is produced in an eco-friendly manner with minimal energy consumption.
- ii This wool is not treated with any chemicals at any stage; it is only washed with home detergents to clear out impurities.

- iii The felted fabric made out of this wool (known as Pattu in the local language) is sturdy and long-lasting, and can last up to more than one generation.
- iv The wool is organic, as the free-range sheep graze on grass and fodder from Himalayan meadows and the livestock is not fed any artificial or factory processed food or supplements.

Habitat

The Gaddi breed of sheep is extant in the Northern Temperate regions of India, and are spread throughout Chamba, Kangra, Kullu, Bilaspur, Simla, Kinnaur and Lahaul and Spiti districts of Himachal Pradesh and Dehradun, Nainital, Tehri Garhwal and the Chamoli districts of Uttarakhand. They are also found in the Kistwar and Bhadarwah areas of Jammu & Kashmir.

The Gaddi Sheep Breed is purely an indigenous breed and shearing of each sheep can yield around half a kilogram of natural wool. The sheep are sheared around 3 times each year.



Figure 1: Gaddi Sheep (Source: Author)

Properties of Gaddi Wool

- i The hair/fiber is about 17-19 cm long and lustrous; one shearing yields around ½ to 1 kg of wool.



Figure 2: Raw Gaddi Wool (Source: Author)

- ii The shorn wool from Gaddi Sheep is dense and fine with a diameter of 29 microns and with 26% medullation.
- iii The colors in which the wool is available is mainly natural white, in addition to natural black, tan and brown colors.
- iv According to the 18th Livestock Census 2007, the number of Gaddi sheep in the country is 338,892. More than half of these are in Chamba district alone.

Socio-Cultural aspects of Gaddi Tribe

A typical Gaddi home is shown in the picture below where the ground floor is used for cattle and for storing fodder. The first floor is where the loom is kept. The women of the household do the weaving in their free time after finishing their daily chores. The traditional spinning wheel, called



Figure 3: House of Gaddi Shepherd in Bharmour District, Himachal Pradesh (Source: Author)

the Charkha, is passed from generation to generation in the

family. Charkha, nowadays are made on specific orders. The wool is used for making fabric for home consumption and the excess wool is sold in open market or to the Himachal Pradesh Wool Board Organization at minimum price set by the Government. The above picture shows a Gaddi woman



Figure 4: Spinning on Charkha (Source: Author)



Figure 5: Hand Spinning Using Wooden Spindle (Source: Author)

spinning the yarn by hand. She chants “Om Namoh Shivay” at the start of every spin. This simple apparatus is taken by the spinner to the pastures during the day and they can spin in an open area, while keeping an eye on the livestock that is grazing around them.

The simple wooden loom is used in the home for weaving Pattu. The wooden shuttle which is hollow from inside is filled with weft yarn manually and inserted between the wraps. Plain weave is used with no color addition apart from base color of natural ecru and black. At times Khadi cotton yarn is mixed with wool to make it less warm. Some weavers have started mixing colorful acrylic yarns along with pure wool. The natural colours of the sheep wool are shown in the figure 8. The Gaddi community is facing a threat of extinction as the traditional source of their survival and subsistence, i.e. the pastures are diminishing day by day due to Governmental policy of turning pasture land into wildlife reserves.

The new generation does not want to take up this traditional



Figure 6: Handloom Weaving Wool-1 (Source: Author)



Figure 7: Handloom Weaving Wool-2 (Source: Author)

life-style that is Spartan and hard, due to the lure of more lucrative occupations. As a result, their textiles and the know-how of sustainable practices too are at risk. There is a danger of extinction of their hereditary livelihood, lifestyle and of their crafts as well as the knowledge of herbs found in Himalayan region which these pastoralists possess. As Gaddi sheep is becoming less and less in the village, the newer generation does not want to take up this profession. Some reasons for this are:

- I Pastures are decreasing due to the Government's policy of declaring forest reserves for wildlife animals like the snow leopard. The state governments also want these pastoralists to settle down so that pastureland can be used for farming. More and more land has been acquired for agricultural use over the years.
- II Construction for Hydel power projects is leading to lot of destruction of natural geology to clear the mountainside and this is damaging the forests and along with it the flora and fauna that inhabit these forests. Gaddis have had to change their usual route for grazing and it leads to new tracks which may not suit the sheep.
- III Temperatures are rising in the Himalayan region due

to global warming. It is said that every year glaciers are retreating by 7-10 meters. The sheep find it difficult to acclimatize to new temperatures that are differing from the usual ones.

- IV Introduction of mixed breed of sheep by Government agencies to increase the yield of meat. This drive to value meat over wool is another factor that has affected the numbers of Gaddi sheep

Owing to these factors, a lot of flocks of Gaddi sheep have already disappeared. The Lahaul and Spiti districts of Himachal Pradesh used to have large flocks of Gaddi sheep but they are not found there anymore, and is a testament to the fact that climate change, and human intervention to chase bigger profits has caused such a decline in their numbers.

The Process of Making Woollen Fabric using Gaddi Wool

The Gaddi tribes make "Pattu" (a felted fabric) and three Pattu yardages are used to make a single overcoat for men called the "Cholu" which has more than two dozen flared panels, stitched side-by-side.



Figure 8: Natural Colors of Gaddi Wool (Source: Author)

The shearing of sheep generally takes place twice a year (April beginning and September end) with simple tools like metal shears. The tribeswomen wash and dry the fleece and subsequently, the Carding is done by hand using a metal comb or given to a ginnery in local area. The cleaned and carded wool fibers are then spun on the wooden spinning wheel (the Charkha) by hand. The resultant yarn is not very strong and to add strength, the yarn is twisted further. The double ply yarn is spun by men with simple wooden spindles called the Katli.

Spinning is done by both men and women. Drop spindle actions can be done while grazing the flock. The loom is traditional handloom, made of wood and is kept at home on the first or the second floor. The shuttle is long and hollow inside where the weft yarn is inserted manually. The fabric is woven in plain weaves in single colour. At times, there are stripes or checks created by adding more colors. There can be mixing of yarn with khadi cotton yarn covered with wool fibers on top. Another variation is that warps of khadi cotton yarns are mixed with wefts of Gaddi wool.

The woven woolen fabric is more than a meter wide and approximately five meters long. It is then felted using mechanical rubbing by stamping with feet and soaping. The process is repeated three to four times to get the desired felt quality.



Figure 9: Innovative Weaves Using Naturally Dyed Gaddi Wool Yarns-1 (Source: Author)

Design Intervention

Owing to its various natural properties, the wool was chosen for design development by the authors.

- I The yarns were dyed in natural colors sourced from flowers, roots and tree barks to add colour variety and make the resultant product more appealing to prospective consumers. The felted fabric of ecru color too was dyed in similar ways.
- II These naturally sourced dyes also impart anti-moth, anti-fungal and anti-microbial properties to the textiles [8]. Natural dyes obtained from various parts of plants such as roots, bark, leaves, flowers, and fruits are believed to be safe due to their nontoxic, non-carcinogenic, and biodegradable properties.
- III The dyes used were – Myrobalan, Pomegranate rind, Madder root (Himalayan Rhubarb), Gavarchini root, Turmeric root, Eucalyptus leaves, Acacia Arabic (Babool tree) bark, and Marigold flowers. The mordant used was Alum and Ferrous Sulphate (known as Kashish in local language) so as to impart color and light fastness. It is known that some plant species exhibit not only dyeing properties but also biological activities including antibacterial,



Figure 10: Innovative Weaves Using Naturally Dyed Gaddi Wool Yarns-2 (Source: Author)

antifungal, anticancer [8].

For instance, coloring component of pomegranate contains hydrolysable tannins, a class of compound which is known to have considerable antimicrobial activity [8].

IV The dying process is eco-friendly and results in fabric that is non-carcinogenic, skin friendly and having a pleasing color palette. The dyes in vat can be re-used within a few days span. The waste water is not harming plants or aquatic life.

V After the dying process, the yarns of different colors were combined in a creative way to make Innovative weaves. However, the patterns were kept geometrical and simplicity was maintained. Images 9, 10, 11 & 12 shows such weave designs. These can be used for making durries, rugs, and blankets on standing loom as well.

The yarns were also crocheted for making handmade home textiles like rugs, cushion covers and 3-D installations for interior space. Some patterns and products shown in Image 13 & 14 depict the versatile nature of wool using zero energy. This handmade product can be easily made by the tribeswomen using crochet hooks.



Figure 11: Innovative Weaves Using Naturally Dyed Gaddi Wool Yarns (Source: Author)



Figure 12: Tapestry Weaves Using Naturally Dyed Gaddi Wool Yarns (Source: Author)

Pollution of environment caused by cleaning plants for wool in commercial set ups

The wool cleaning and processing plants throws up some alarming facts from an environmental perspective. Such commercial and industrial processes and facilities consume high levels of Non- renewable energy; chemical wastes generated by these plants pollute land and water; this chemical pollution further affect human, marine life and aquatic plant life; and also poison the natural aquifers. Residual harmful chemicals still remain impregnated in these industrially-produced textiles which are absorbed by humans using them, and their noxious presence causes various health problems for the humans.

The various stages of a commercial wool production and processing causes damage to the environment and human and plant life, as explained below:



Figure 13: Crochet Structures and Patterns-1(Source: Author)



Figure 14: Crochet Structures and Patterns-2 (Source: Author)

I *Washing stage*- Wool needs a lot of washing as fleece of sheep may contain dirt, grease, and vegetable matter. In the traditional method, wool is washed using simple warm water and mild detergent. In the commercial method, industrial-grade detergents, alkalis and petrochemicals are used. Apart from chemicals, the resultant waste water has high amount of grease, and this grease promotes the growth of Algae in rivers and water bodies, which decimates fish populations as thick layers of algae reduce oxygen level in the water.

Detergents used in wool scouring include Alkylphenol Ethoxylates (APEOs) or fatty Alcohol Ethoxylates (more benign); sodium carbonate (soda ash), Sodium Chloride and Sodium Sulphate. APEOs are among those chemicals known as endocrine disruptors, called so as they interfere with the body's endocrine system of marine life.

II *Treatment stage* – The commercial wool is soft to the touch as compared to traditional wool produced in rural areas such as Gaddi wool. Also, the pure form of wool is susceptible to attack by moths and beetles. Wool fibre has a covering of scales like barbed wire making it feel itchy. Treatment plants use chlorine treatments and polymer coating to imparting descaling and anti-shrinking property in

wool making wool feel smoother, comfortable and not itchy. However, this process results in high levels of toxins in waste water. For example Adsorbable Organohalogens (AOX) are one of the most toxic substance, and in the US, this waste water is not even accepted to treat in effluent treatment plants. Therefore, all chlorinated wool is processed in other countries and then imported into the US.

III *Dyeing stage* - Chemical dyes used to colour wool creates a lot of water and soil pollution. Some dark colours use chrome based dyes which are carcinogenic to skin and harmful for plants and marine life.

IV *Weaving stage* – The modern weaving methods employ machine looms to weave large quantities of textiles, to fulfil economic goals. These mechanized looms consume Non-renewable sources of energy and the factories generally operate in unsanitary and chemical-riddled conditions for the workers.

V *Finishing stage* - Wool is often treated for moth and beetle protection, using Pyrethroids, Chlorinated Sulphonamide derivatives, Biphenyl ether or Urea derivatives, which cause damage to the brain or peripheral nervous system.

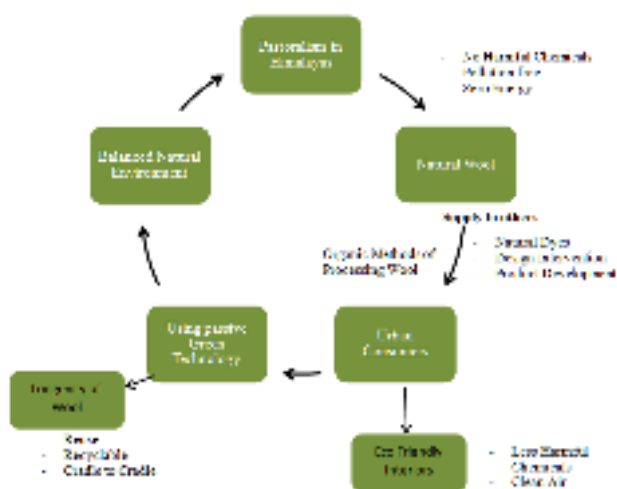


Figure 15: Model of Sustainability from Pastoralist to Consumers

Gaddi Wool in Circular Economy Context

To summarise, Gaddi wool from the Himachal region is an amazing fibre, and what makes it unique is the structure of its fibres which absorb moisture, insulate against heat and cold, resist flame and maintain their resilience. The felted fabric “Pattu” is a very good water repellent fabric that is used by shepherds to protect themselves and the lambs in harsh and cold weather. The same fibre and/or fabric used in interiors have a very good potential to make the indoor environment pollution free because of its properties. This natural material when used in interiors can act as a good sound-resistant acoustic material. Moreover, the wool felt can be used as an insulation material for heat and sound. The contemporary designs created using handmade techniques add to the aesthetics apart from the inherent functional benefits.

Owing to the sustainable process used in its manufacture and eco-friendly character, this wool is proposed here as an integral component of a circular model of economy for interior textiles.

Firstly, any product or by-product in the process of Gaddi wool production and product development is reusable, recyclable and renewable due its organic nature and longevity. This aspect aligns well with the “cradle to cradle” concept of circular economy. Secondly, the entire process is in sync with balanced eco-systems of Mother Nature, preserving the depleting natural resources of the Himalayan region and its inhabitants including flora and fauna. The wool products designed for interior spaces of hilly as well as urban areas will help in absorbing harmful environmental pollutants.

The green nature of the process as well as the balanced lifestyle of Gaddi shepherds makes this system aligned to the Circular Economy concept where wastage of material and resources is minimal and the carbon foot print is negligible due to non-usage of electrical energy and harmful chemicals. The manufacture of this hand-spun and handloom fabric is done manually and is a slow process which can become more efficient if we introduce the Ambar Charkha (solar energy driven handloom spinning wheel) during the manufacturing process.

The ideas for interior product development will also generate job opportunities for local women and men who are currently doing it only for home-consumption. The youth of the Gaddi tribe can take up this textile-based craft as an attractive mean of livelihood and this will open up new avenues for them while collaborating with design and business entities, creating new synergies.

“In the cycles of the natural world, nothing is wasted: everything old becomes food for something new. This simple, safe and successful design concept has governed our living planet since the beginning.” - William McDonough [9].

This proposed model as shown in the diagram below may help in preserving the culture, heritage and lifestyle of this pastoralist community and prevent the depleting number of sheep in that region. More sheep population will result in better soil quality due to composting process of sheep droppings being used in the fields as manure. The design intervention ideas may result in improving the usable value of products for contemporary customer taste.

Overall, the proposed model will help all the stakeholders in the chain starting from the rural craftsman, the indigenous sheep flock, the traditional culture, current interior scenario and users in urban habitat while maintaining the balance of the natural resources.

Authorship contribution

Seema Chaudhary: Conceptualized the review, conducted the literature search, and drafted the first draft. Responsible for the review of the major findings and summarizing the information regarding historical and theoretical considerations, formatting, and ensuring adherence to journal guidelines.

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Similarity Index

I hereby confirm that there is less than 10% Plagiarism was achieved in this review paper.

Data availability statement

All data supporting the findings of this review are included within the article and its supplementary materials. Additional information is available from the author upon reasonable request, ensuring transparency and accessibility.

Declaration

Authors hereby declare that this is original work and has not been submitted or published elsewhere. All sources used have been properly cited, and any external contributions have been acknowledged.

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