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Ecological textiles to promote sustainability

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Abstract

The development of clothing from fibre to fabric stage requires a lot of processes that are harmful to the human and environment because the current operations of textile industry are unsustainable and companies, environmentalist and consumers are searching for strategies to reduce the carbon footprint of textiles. Recently, various technologies and innovations related to textile production have been developed to save the world from the dangerous effects of chemicals and to protect the mother earth. Different preventive measures have to be taken and technologies should be developed which can maintain the balance of the ecosystem and make the final textile product free from toxic effects. In general, there is really no such thing as 100 percent eco-friendly clothing as all garments requires water for the fibres to grow and energy to make the fabric and the finished garment. Eco-friendly clothing can be termed as clothing made of natural fibres, organically dyed with natural dyes or fabrics that use very little water, energy or chemicals that have a positive impact on the environment. Natural fibres are particularly attractive because of their unique properties such as mechanical strength, light weight and wearer safety. Therefore, this review presents an overview of the textile industry highlighting the ways to make textile industry more ecological.

Keywords: ecology, textile and apparel industry, environmental impact, sustainable textiles

Introduction

The term "ecology" was coined in 1866 by the German Scientist Ernst Haeckel (1834-1919). Ecology is the scientific analysis and study of interactions among organisms and their relationship with natural environment which is conceived to include everything that is not an intrinsic part of an organism and thus includes both living and non-living components like water, atmosphere and pollutants. The pollutants in water and air are naturally present, such as microorganisms or are introduced by humans through industrial gases and effluent. These pollutants interfere with the natural growth of living organisms such as plants, animals and humans. Therefore, insecticides, pesticides, herbicides, chemical wastes, nitrogen and sulfur oxide gases, formaldehyde, chlorine, oil spills and radioactive pollutants have a direct impact on the ecology of a particular area [3].

Ecology is an interdisciplinary field including biology, geography and earth science. In the textile field, ecology plays an important role for example; a "Natural Textile" may be assumed environmental friendly by definition just because it has been made without bleaching and dyed with natural dyes. In general, the aim is mainly to ensure the human safety aspects of clothing without compromising fashion and function. Ecological balance can be defined as a state of dynamic equilibrium within a community of organisms in which genetic, species and ecosystem diversity remain relatively stable, subject to gradual changes through natural succession [6].

The textile industry is considered to be the most polluted industry in the world. The ecological problems of the textile industry are caused by several manufacturing processes and are carried over to the finished product. In the production process such as bleaching and dyeing, the subsequent fabric makes a toxin that swells into the ecosystem. All textile products release wastewater that is harmful to the environment. The traditional textile industry consumes large amounts of earth's natural resources and pollutes the environment as their production and processing involve chemical intensive applications, therefore, eco-textiles are needed. Eco-textiles mean clothing and other accessories that are designed to use the organic and recycled material [10, 13].

Generally, there are four main environmental key factors related to the production of textiles that are water, energy, pollution and use of non-renewable resources. During the production process, controlling pollution is as essential as making a product free from the toxic effect. The use of rayon for clothing has added to the fast depleting forests and opened the door to the

development of natural sustainable fibres such as organic cotton, hemp and bamboo fibres. Organically produced fabrics can replace regular products. Reducing the environmental impact throughout the life cycle of a fabric item or using lower impact products can contribute actively to improve the situation ^[16].

Factors affecting the ecology

Acid Rain: Acid rain is precipitation that contains harmful amounts of nitric and sulfuric acids. These acids are mainly formed from nitrogen and sulfur oxides that are released into the atmosphere when fossil fuels are burned. These acids fall on earth as either wet precipitation (rain, snow, fog) or dry precipitation (gas and particles); some are carried by the wind while others are carried hundreds of miles. In the environment, acid rain damages trees, acidifies soils and water bodies making them unsuitable for some fish and other wildlife. It also speeds the decay of buildings, statues and sculptures that are part of national heritage ^[12].

Eutrophication: Eutrophication is derived from the Greek word 'eutrophos' that means well-nourished or enriched. It is the excessive presence of nutrients such as nitrate and phosphate in a lake or other water bodies which causes a dense growth of plant life. Springs, streams, lakes are categorized as oligotrophic (poor nutrient content), mesotrophic (moderate nutrient content) and eutrophic (high nutrient content) based on various contents including phosphorus, nitrogen and calcium. Eutrophication is a condition in a water body where high concentrations of nutrients stimulate blooms of algae that can kill fish and cause loss of plant and animal diversity. Even though, eutrophication is a natural process in the aging of lakes, human activities can significantly accelerate eutrophication by increasing the rate at which nutrients enter the aquatic ecosystem ^[4, 12].

Haze: Haze occurs when sunlight encounters tiny pollution particles in the air. It obscures the clarity, color, texture and form of what is seen. Some haze-causing pollutants are released directly into the atmosphere from sources such as power plants, industrial plants, automobiles and construction activities. Others are formed when gases emitted to the air like sulfur dioxide and nitrogen oxides form particles as they are carried downwind ^[1].

Ozone depletion: Ozone is a gas that occurs both on the ground and in the upper atmosphere of the earth, the so-called stratosphere. At ground level, ozone is a pollutant that can be harmful to human health and in the stratosphere; ozone forms a layer that protects life on earth from the harmful ultraviolet rays (UV) of the sun. It is gradually being destroyed by man-made chemicals known as ozone-depleting substances that include chlorofluorocarbons, hydro chlorofluorocarbons and halogens. These substances were previously used and sometimes still are used in coolants, foaming agents, fire

extinguishers, solvents, pesticides and aerosol propellants. Thinning of the protective ozone layer can increase the amount of UV light that reaches the earth which can further increase the number of cases of skin cancer, cataracts and weakened immune system. UV can also damage sensitive crops like soybeans and reduce crop yields ^[10, 16].

Global climate change: The earth's atmosphere contains a delicate balance of naturally occurring gases that trap some of the sun's heat near the surface of earth. This greenhouse effect keeps the earth's temperature stable. Unfortunately, there is increasing evidence that humans have disturbed this natural balance by producing large amounts of the greenhouse gases like carbon dioxide and methane as they trap heat like a glass roof in a greenhouse. As a result, the earth's atmosphere appears to trap more heat from the sun raising the earth's average temperature; a phenomenon known as global warming ^[24].

Areas of textile ecology

1. Production Ecology: Production ecology examines the impact of production processes on people and environment like occupational health and safety, material, water and energy consumption, waste water and waste treatment as well as generation of dust and noise. It comprises of growing and harvesting of natural fibres, production of manmade fibre, threads and fabrics, bleaching, dyeing, printing and finishing of textiles, garment manufacturing with the application of fertilizers, growth regulator, crop protection agents (pesticides etc), dyes, pigments, textile chemicals auxiliaries and finishing agents ^[25].

Production Ecology and Textile Industry

Today, the biggest challenge facing the textile industry is to change production methods to be more environmentally friendly by using safer dyes and chemicals at competitive prices and reducing wastewater treatment/disposal costs. Recycling has become a necessary factor not due to shortages of items but because pollution needs to be controlled. There are three ways to reduce pollution that include using new, less polluting technologies, effectively treating wastewater to meet established emission requirements and recycling waste multiple times before discharge ^[13].

Alok Industries' focus on sustainability-related activities is at the core of its long-term goal of becoming a leader in delivering sustainable and integrated textile solutions. They are committed to achieve the lowest specific energy consumption per unit of product, thus minimizing greenhouse emissions, solid waste and water pollution; to attain sustainable development by continuously improving energy conservation and energy efficiency throughout the production cycle; to prevent wastage of energy in any mode i.e. steam, water, air or power - by efficient and most optimal use of resources; to comply with all applicable legislations and best practices on Energy Management Community Development ^[14].

Possible Treatments for Textile Wastes

Process	Advantages
Biodegradation	Rate of elimination by oxidizable substances about 90%
Coagulation-flocculation	Elimination of insoluble dyes
Adsorption on activated carbon	Suspended solids and organic substances well reduced
Ozone treatment	Good decolorization
Electrochemical processes	Capacity of adaptation to different volumes and pollution loads

Reverse osmosis	Removal of all mineral salts, hydrolyzes reactive dyes and chemical auxiliaries
Nanofiltration	Separation of low organic compounds of low molecular weight and divalent ions from monovalent salts.
Ultrafiltration-microfiltration	Low pressure

Desizing: Generally, about 50 percent of the water pollution is because of waste water from desizing which has a high BOD that makes it unusable. This problem can be alleviated by using enzymes that breaks down starch into ethanol instead of hydroglucose. The ethanol can be recovered by distillation and can be used as a solvent or fuel, reducing BOD load. On the other hand, an oxidative system such as H₂O₂ can be used to completely degrade starch into CO₂ and H₂O [17].

Bleaching: Hypochlorite is one of the oldest industrial bleaching agents. The formation of highly toxic chlorinated organic by-products during the bleaching process is reduced by adsorbable organically bound halogen (AOX). An environmentally friendly alternative to hypochlorite is per acetic acid which decomposes into oxygen and acetic acid that is fully biodegradable. One of the advantages of peracetic acid is less fibre damage and higher brightness. Currently, a one-step preparatory process for desizing, scouring and bleaching has developed to reduce the amount of water [13].

Neutralization: Replacing acetic acid with formic acid to neutralize the fabrics after cleaning, mercerizing, bleaching and reduction processes is considered effective, economical and environmentally friendly. This process also allows for sufficient neutralization in a short period of time, requires very little water and reduces BOD content [20].

Dyeing: Dye baths are usually heavily contaminated for example wastewater produced by reactive dyeing contains hydrolyzed reactive dyes not fixed on the substrate that accounts for 20 to 30 percent of the reactive dyes applied at an average of 2 g/l. This residual amount is responsible for the coloration of the effluents and cannot be recycled. Dyeing auxiliaries or organic substances are non-recyclable resulting in high BOD/COD in wastewater. Measures adopted to reduce pollution by different dyes include use of low material-to-liquor ratios, use of tri-sodium citrate and replacement of reducing agent (sodium hydrosulphite) with a reducing sugar or electrochemical reduction [19].

Printing: In India, a majority of textile printing units prefer to use kerosene for printing due to the brilliant prints and ease of application. In India alone, about 122 million liters of kerosene is released into the atmosphere during printing, drying and curing annually. The resulting pollution of the atmosphere and wastage of hydrocarbon products is colossal. Air-laden kerosene is harmful to human beings as well as to the flora and fauna in the neighborhood. Printing is mostly done by a flat or rotary screen and after every lot of printing some residual paste is left in the wastewater. This can be reused for printing of similar shades by adding new stock. Currently, screen-free printing methods like ink-jet printing and electrostatic printing have been developed that make use of an electronic control of color distribution on fabric. Screen-free printing methods are attractive for mitigating pollution [19, 20].

2. Human Ecology: Human ecology deals with the impact of textiles and their chemical ingredients on the human health and well-being. The irritation from textile clothing can be

uncomfortable for the wearer and can cause physical effects such as dermatitis due to many factors, including the manufacturing process of the garment. The wearer's personal preference may also influence a perceived comfort of the garment [8].

In a study by the National Institute of Occupational Health (1998), the work stresses of 107 women engaged in sewing in small-scale garment manufacturing units found that 68 percent of the women complained of back pain and these problems had persisted over a long duration. WHO (1998) carried out a study on readymade garment workers in Bangladesh on a sample size of 150 women who reported health problems like pain in the upper and lower limbs and other aches and pains. Around 80 percent of the workers experienced this kind of illness quite often. This was followed by backache, which was reported by 47 percent. The major reason was the posture adopted while working. Salnaggio (1986) described the word Byssinosis is derived from the Greek word "Bussus" meaning fine Linen or fine flax. Byssinosis is a respiratory disease of workers of cotton, flax, soft hemp and is classically characterized as shortness of breath; cough and tightness of chest. The noise is a cause, which created hazard in the work place. Noise exposure at work can cause critical hearing damage. It is one of the most occurring health problems which can be difficult to identify because the effects build up slowly with time [8, 11].

3. Performance Ecology: Performance ecology comes in at the usage phase of textile products. It investigates the environmental impact of washing, cleaning and caring for textiles. The Ecology of Human Performance was founded by occupational therapists at the University of Kansas in 1994. The main focus is on the interdependence of human-environment relationships and how this relationship affects human performance [9, 17]. It includes:

Establish/Restore: This occurs at the level of the person whose skills and abilities are the focus of the intervention. The purpose is to restore function by improving skills and abilities. This remediation process takes place within context.

Adapt: The context manipulated and structured to support performance. Task demands can also be adapted to enable performance.

Alter: The intervention focuses on choosing the context that enables performance with the person's current skills and abilities. This means finding the right context, rather than changing the current context to meet the abilities.

Prevent: The occurrence or evolution of maladaptive performance is prevented. Prevention is the main focus of intervention. This can be done by addressing the characteristics of people, tasks and contexts that may lead to inconsistent performance.

Create: Circumstances that promote more adaptable or complex performance within context are created. This intervention strategy aims to promote overall functional performance without assuming that it may fail or impair

performance.

4. Disposal Ecology: It analyses the problems associated with disposal, reuse, recycling and removal i.e. thermal recycling or landfill of textiles in a manner that ensures the least possible environmental impact ^[2].

Chemicals restricted and prohibited in textile industry

Chlorine: It is prohibited for bleaching due to generation of organic substances of which some are supposed to be carcinogenic like chloroform.

Formaldehyde: It is a toxic chemical, a skin irritant and sensitizer. Animal inhalation tests with high concentrations have indicated a nasal carcinogenic in rats and mice. Thus, it is restricted in consumer products such as cosmetics and textiles ^[1].

Heavy metals: Heavy metals like cadmium, lead and mercury have been used in certain dye and pigments used for textiles. These metals can accumulate in the body over time and are highly toxic with irreversible effects including damage to the nervous system (lead and mercury) or the kidneys (cadmium). Cadmium is also known to cause cancer ^[7].

Pesticides: They are organic or inorganic substances used to destroy or inhibit the action of plant and animal pests. It includes insecticides, herbicides, rodenticides etc. These are harmless to man as they rapidly decompose into non-toxic compounds i.e. nicotine and copper naphthanate. Due to harmful ecological effects, Dichloro Diphenyl Trichloroethane (DDT) has been banned for agriculture applications ^[18].

Pentachlorophenol: It has a very pungent smell and is insoluble in water but soluble in ethyl alcohol ether and benzene. Ingestion causes increase and then decrease of respiration, blood pressure, fever, liver damage and contact dermatitis. It is absorbed through skin and is more toxic in organic solvents ^[10].

Sustainable clothing

Sustainable clothing is the fabric derived from eco-friendly resources like sustainably grown fibre crops or recycled materials. Environmentally conscious towards clothing means buying clothes from thrift stores or any shops that sell secondhand clothing and donating used clothes to shops for reuse or resale. In modern times, with a prominent trend towards sustainability and being green, sustainable clothing is generally preferred as they reduce the amount of garments that go to landfill and reduce the environmental impact of pesticides on the production of traditional fibre crops such as cotton ^[15].

BT Cotton: To reduce the use of pesticides and other harmful chemicals, companies are producing genetically modified (GMO) cotton plants that are resistant to pest infestations. Among the GMO are cotton crops inserted with the BT (*Bacillus thuringiensis*) gene. BT cotton crops do not require the application of pesticides and insects that consume cotton containing BT will stop eating after a few hours and die, leaving the cotton plants intact ^[21].

Organic Cotton: It is cultivated without the use of any

genetically modification to the crops, without the use of fertilizers, pesticides or other synthetic agro-chemicals that are harmful to the land. It is very soft to touch and eco-friendly. Another promising trend from a sustainability standpoint is the production of colored cotton or natural dyes which can further reduce the use of chemicals ^[23].

Soy Fabrics: This fabric is made from soy protein left over after processing soybeans into food. The liquefied proteins are extruded into fibres which are then spun and used like other fibres. Soy fabrics can be blended i.e. 30 percent or made entirely out of soy fibres. Soy clothing is mostly biodegradable, so their impact on the environment and landfills is minimal. Although not as durable as cotton or hemp fabrics, soy clothing has a soft, elastic feel and is known as the vegetable cashmere for its light and silky sensation and has moisture absorbent, antibacterial and UV resistant property ^[6].

Bamboo Fabrics: These are made from heavily pulped bamboo grass. The production of clothing and textiles from bamboo is considered sustainable as there are no pesticides or agro-chemical requirements. The main reason which makes it consider as an eco-friendly fibre is its renewable property. It has natural anti-bacterial properties and is comfortable, soft, lustrous and absorbent due to which it has wider applications ^[12].

Corn Fibre: Corn is available in both spun and filament forms. It comes from naturally occurring plant sugars. It balances strength and resilience with comfort, softness and drape in textiles. Corn is also flame-retardant in nature with no chemical additives or surface treatments so it can be used in sportswear, jackets, coats, apparel etc. ^[3]

Banana Fibre: The use of banana stalks as a source of fibre such as cotton and silk is becoming very popular today. It is used all over the world for a variety of purposes such as making tea bags or sanitary napkins to Japanese yen notes and car tyres. It is also known as musa fibre that is one of the strongest natural fibres. Banana stem, hitherto considered a complete waste, is now being made into banana-fibre cloth which comes in differing weights and thicknesses based on what part of the banana stem the fibre was taken from. The softest fibres are obtained from the innermost layer and the thicker and stronger fibres are obtained from the outer layer. The high water absorption capacity of this fabric makes it cool to wear ^[3].

Milk Fibre: Milk fibre was firstly introduced in 1930 in Italy and America to compete the wool. This is a new and innovative fibre, a type of synthetic fibre made from milk casein through bio-engineering method. It can also be used to manufacture high quality underwear, shirts, T-shirts, loungewear, etc. It contains seventeen amino acids and natural anti-bacterial rate is above eighty percent hence, milk fibre has sanitarian function ^[5].

Hemp: It is considered a sustainable crop, requires very little water to grow and is resistant to most pests and diseases. Unlike cotton, it has many uses in many parts of the hemp plant, such as the processing of hemp seeds into oils and foods. Hemp fibres are durable and are considered strong enough for construction uses. It is about 8 times stronger and

4 times more durable than cotton fibre. Hemp fibres are traditionally coarse and have been used in the past for ropes rather than clothing. However, modern technology and breeding practices have made hemp fibres softer, pliable and finer ^[14].

PET Plastics: Also known as polyethylene terephthalate (PETE), these plastics are usually beverage bottles i.e. water, soda and fruit juice bottles. Recycling plastic reduces air, water, and ground pollution which is only the first step; investing and purchasing products manufactured from recycled materials is the next of many steps to living sustainably. Seventy percent of plastic derived fabrics come from polyester and the type of polyester most used in fabrics is polyethylene terephthalate (PETE). The Coca Cola Company, for example, created a "Drink2Wear" line of T-shirts made from recycled bottles. Main benefit of making clothes from recycled bottles is that it keeps the bottles and other plastics from occupying landfill space. Another benefit is that it takes 30 percent less energy to make clothes from recycled plastics than from virgin polyesters ^[22].

Recent innovations in ecological fabrics

Samatoa/Lotus Fabric: Fabrics extracted from lotus flower is known as Samatoa. Lotus plant is believed to have healing abilities and wearing a fabric made from lotus fibres is also believed to have the same effects. Lotus plants are pure by virtue and they radiate this purity through their fibres. By wearing lotus fibre fabrics, the wearer feels calm, peaceful and meditative. It also cures the wearer from headaches, heart ailments, asthma, and lung issues. The fabrics are 100 percent organic so it is environmentally friendly. The entire process of fibre extraction, spinning it into yarn and making the fabric is completely handmade making this process time consuming. This disadvantage also limits the quantity of the fabric produced ^[25].

Fabrics from Fermented Wine: A group of scientists at the University of Western Australia has produced fabric by letting microbes to work on wine. It is produced by adding bacteria called Acetobacter into cheap red wine. The bacteria ferment the alcohol into fibres that float just above the surface. These fibres can be extracted and fashioned into clothing. Since Acetobacter produce vinegar as its end product, the garments have a definite odour ^[2].

Hagfish Slime Thread: These fibres are obtained from the goo attached to a hagfish, an eel-shaped bottom-dwelling animal of the deep sea. It is the only known creature to have a skull, but no vertebral column. Scientists have discovered that proteins within this slime have mechanical properties similar to those of spider silk and can be woven into high-performance bio-materials ^[8].

Cocona Fabrics: Cocona is a fabric that is produced from fibrous coconut husks which incorporates natural ingredients into polymers. By using activated carbon made from coconut shells, cocona fabric uses natural technology that outperforms other fabrics and yarns. Cocona fibres and yarns can be used in a wide variety of knit and woven fabrics as well as non-woven that provide effective evaporative cooling, odour adsorption and UV protection. Fabrics made from cocona yarns and fibres are lightweight, comfortable and retain all of the conventional product features like stretch and washability

^[17].

The organic and ecological textiles continue to grow, driven by growing consumer awareness of the risks of traditional textiles to health and the environment. To ensure the customer in a responsible project, it is important to ask for a control of goods or activities in order to guarantee the organic or ecological propriety ^[24]. For that, Ecocert offers to certify according to:

- GOTS (Global Organic Textile Standard) for a social and environmental responsibility.
- OCS (Organic Content Standard) to guarantee the traceability of organic textiles.
- Ecological & Recycled Textiles (Ecocert Standard) to claim the environmental quality.

Eco-trademarks: A number of trademarks and labels for textiles made available by associations, institutions and the service companies of textile industry. Fabrics intended for these labels must meet certain requirements, which are common to most of the labels ^[25]. These are:

The fabric must contain no dyes that are considered as carcinogenic or can cause allergy, it must not release dyes on contact with saliva, the concentrations of heavy metals released on contact with perspiration must not exceed limits of drinking water, the level of pesticides residues must not exceed the permissible limits for foodstuffs, the level of free formaldehyde should not exceed the legal limit and the pH should fall within the pH range for human skin.

Eco-labels for textile industry

- **Eco-Tex:** Label of Eco-Tex Consortium.
- **EPG:** The European product guarantee of ELTAC (European largest textile and apparel companies).
- **GuT:** Label of environmentally sound carpet association.
- **GuW:** Label of environmentally sound furnishing fabrics association.
- **Oko-Tex Standard:** Label of the international association for research and testing in the field of textile ecology ^[11].

Conclusion

Ecological textiles are gaining importance in the consumer market. Consumers who initially considered only the aesthetic value of the clothes are now noticing at the dangerous effects created by various chemicals. It is better for the society to prevent pollution than to cure it after its creations. Environmental protection and eco-friendliness play an increasing part in consumer awareness today. As the textile industry become aware of it, efforts are being initiated in the production and export of eco-friendly textiles. There are various eco-friendly fibres that are available in the market which are designed for the purpose of reducing the harmful substances used in the textile production like bamboo, hemp, corn fibre etc. Even though many fibres and fabrics are available, new innovations can be made in the field of eco-textiles which can protect the environment from further depletion. Fashion is not something that exists only in dresses. Fashion is in the sky, in the street; fashion has to do with ideas, the way we live, what is happening. So it is important to go green and make fashion more eco friendly.

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