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Polymer Composites in Green Technology: A Review

Minakshi Padhy
Siksha 'O' Anusandhan (Deemed to be University), moon.94371@gmail.com

P. G. R. Achary
Siksha 'O' Anusandhan (Deemed to be University), pgrachary@soa.ac.in

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Minakshi Padhy
Department of Chemistry, Siksha 'O' Anusandhan (Deemed to be University), Khandagiri Square, Bhubaneswar- 751030 India

P.G.R.Achary*
Department of Chemistry, Siksha 'O' Anusandhan (Deemed to be University), Khandagiri Square, Bhubaneswar- 751030 India

Abstract: Rapid depletion of fossil resources, high demand for energy and global warming together encourage us to look for renewable polymer items with low carbon.'Green monomers' could be derived from bio-refineries, biowastes or renewable oil, plastics-waste. The polymer obtained from such green monomers are renewable and can display good characteristics equivalent to the traditional polymers or sometimes better than the existing polymers. Green technology is a global movement to create vibrant and sustainable cities. Green technology addresses social, economic and environmental values and creates a green economy. Green technology is based on the process of using waste materials for beneficial purposes by managing, and recycling the waste. This technology involves the waste treatment, incineration and management. Many materials prepared form green composites are cost effective in-terms less consumption of electricity, andwater,at the same time a significant decrease in CO_2 emission, and solid waste generation.Thepresent review presents the effective techniques, difficulties, applications& information on bio-polymers, naturalfiber reinforcements, propertiesof the different green composites and recommendations.

Keywords: Green composites, Biofibers, Biopolymers, Interfacia strength,Fiber dispersion, Fiber defects, Strength, Crystallinity, Inner structure, Green technology

1. Introduction

Green technology deals with the science and technology which is developed to save our environment. Many techniques are studied andtrying to invent for better green technology by using green chemistry. The main aim of green technology is to protect the environment from chemical hazards and breathe life back into a damaged ecosystem. This is also known as clean technology. This technology saves the earth to continue for existenceof healthy life. Green technology is based on the process to use waste material for beneficial purposes by managing and recycling the waste. This technology involvesthe wastetreatment,and incineration and management. Ingreen technology there are observed many advantages like purifying water, reducing carbon emissions and purifying the air, good ecosystem. As, by using green technology more trees are planted, crops are cultivated and waste is managed and recycled, which manages our daily needs.

"Green" polymers arepolymersthat are prepared partly/fully from natural resources (renewable) besides petroleum. These are widely distributed materialsthat areobtained from biosources(like microorganisms, plants, or trees). The global awareness due to different issues of the environmenthas increased the production of sustainable and environment friendly green composites or materials, which can be recyclable, biodegradable and also from renewable sources.A green composite is a material, which consists of two different phases (Fig.-1), generally a matrix or continuous phase and a disperse phase. The dispersed phase contains natural fibers and the matrix phase is derived from natural polymer. The third one required for the green composite, is the interface which helps to bind disperse phase and matrix into a composite. For surface treatments, interfaces (silane, acetone and alkali treatment etc) are used to enhance the mechanical behaviors of green composites[1].

Green composites are future sustainable composites where natural fibers and natural resins play an important role in making lightweight and stronger composites that can be recyclable and biodegradable.

Different types of renewable green composites are introduced like:

i. Wood derived composites
ii. Bamboo derived composites
iii. Other plant(leaf, fruit, grass)fiber composites
iv. Bioresins and biopolymers composites originated from natural resources like animals and plants
v. Cellulose and nanocellulose composites

We can say that these materials are produced by synthetic chemical processes from bio-sources like oils of vegetables, sugars, resins as well as proteins andamino acids etc.[2]. For long years back, humans are using polymers in daily life. From long years backB.C. humans produced clothes from animal skins; 24,000years back humans used plant fibers for many product formations; 10,000 years backflax, ramie,and jutefibers were used; 9000 years backwool; 5000 years back silk, and 3000 years back cotton were used by humans in their daily life.[3]. In the 1220s, pigments produced from the Asian lac bug were used for paintings which area thermoset resin[4]. During the year 1751, F. Fresneau studied the behaviorsof natural rubber, derived from the Pararubber tree in South America. Many scientists were attracted to the properties ofnatural rubber and in 1860, an English chemistG.Williams discovered isoprene by distilling naturalrubber. After 10 years, J. W.Hyatt (1870) designed celluloid (athermoset) which was prepared from the combination of camphor and cellulosenitrate. At that time Celluloids was usedespecially for toiletry items as well as collar-stays,combs, and for photography cases, and to prepare the 1st flexiblephotographic films[4]. In 1900,J. E. Brandenberger (Swiss chemist) prepared a lean transparentsheet, cellophane from restored cellulose, which was used for packaging.In the same year rayon was also prepared fromrestored cellulosewhich was generally used in markets of apparel and furnishing. In 1940s, many experiments on soybean-based composites were startedby Henry Ford and few of them were usedin different auto parts.

As we are becoming more concerned abouta healthy environment, good ecology, and less consumption of petroleum resources, to achieve our goal the thirstiness for developing new green composites increases day by day. The classifications, processing techniques and applications of green composites are cited in this review after studying many references for this research work.

2. Green Composites

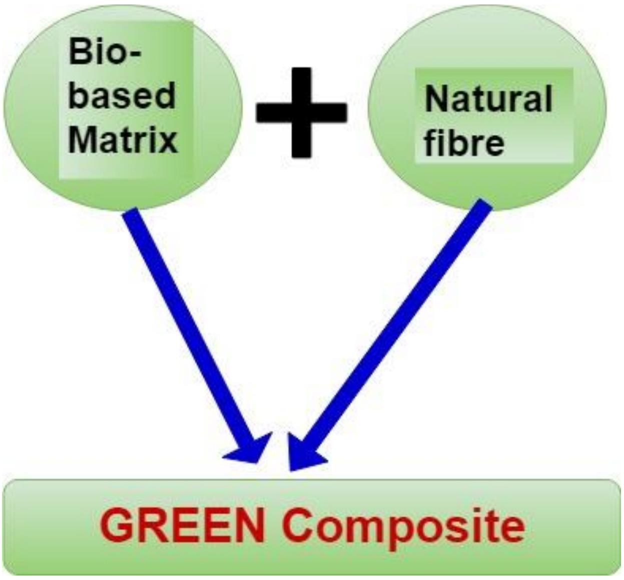

Fig. 1 Green composite from natural fiber and bio based matrix

Green composites are composed of natural fiber and bio based matrix (Fig-1). Natural fibers are classified into three parts (Table-1) i.e.Animal fibers, Nonwood fibers and Woodfibers,from where we get plenty ofcellulose, proteins and lignin. Animal fibers basically comprise of proteins, and have potential reinforcements in composites. The Nonwood fibers are widely used in industries for their more attractive physical, chemical and mechanical properties. These fibers are actually lengthyfibers, with plenty of cellulose and good mechanical effects like tensile strength and degree of crystallinity. The wood fibers have more than 60% of wood particles. The wood fibers are two types, softwood fibers and hardwood fibers. The softwood fibers are lengthy and flexibility in nature, whereas hardwood fibers are not lengthy and stiff and have low degree of cellulose crystallinity. In the industry one of the most frequentlyapplicablefibers is jute.

Table-1. Some Biofibers and their origins

Biofibers									
Animal Fibers			Nonwood plantfibers						Wood based fibers
Silk (Silkworm, spider, from the larvae of butterfly species)	Chicken fiber (Chicken feathers)	Wool (Sheep, goat, camels, rabbits, and certain other	Straw basedfibers (Rice, wheat, corn straws)	Bast (Kenaf, flax, jute, hemp)	Leaffibers (Henequen, sisal, pineapple and banana leaf fiber)	Seeds/fruits Fibers (Cotton, coir, coconut, palm oil , and other	Grass basedfibers (Bamboo, bamboo fiber, switch grass,)	------ Soft wood (Kraft (spruce)) and hard wood(Kraft (spruce)) --------- (Newspaper,

		mammals.)				vegetable oils)		magazine fibers)

For production of green composite materials, there are required natural fibers (hemp, flax, jute, kenaf, and sisal etc on the place of synthetic non bio fibers) (Table-1)and matrix materials derived from biopolymers/bio based resins (starch, vegetable oils, and protein). The natural fibers are used in many sectors alone or by forming composites (Table-2). Examples of bio-polymers are starch, Poly lactic acid (PLA), Poly-L-lactic acid, Starch , bio based Polyesters, Cellulose acetate, Furfural alcohol and Furan resins, Poly (butylene succinate), CNSL(Cashew nut shell liquid) etc. In Table-3 there are some bio materials, which are used for synthesis of bio based polymers.

Table-2. Different natural fibers with their uses :

Natural fibers	Uses
Jute fiber	Pilot's cabin door and door shutters
Bast fibers and jute fibers	Interior door panels, door trims
Banana fiber composites/coir/sisal fibers	Automotive seat shells
Sisal fibers	Heater housings
Flax/kenaf/hemp/jute fibers	Package trays, truck liners, door trims and under body coverings
Flax/jute/sisal/banana/ramie fibers	Interior aircraft applications, flooring.

Table-3. Some biopolymers and their starting material-

Bio based polymers	**Starting material**
Polyester or poly-3-hydroxybutyrate (PHB)[5]	Glucose and Glycerol
Polyamide 11[6]	Castor oil
Polyurethanes[7]	Vegetable oils
Polyether polyols[8]	Castor oil
Poly Styrene[9]	Glucose
Poly Lactic acid[9]	Glucose, Glycerol

Natural rubber[9]	Mevalonate
Poly Propylene glycol[10]	Glycerol
Epoxy polymers[11]	Cardanol

3. Factors affecting mechanical performance of green composites

3.1. Selection of Fibers

Generally,fibers are categorized based onits origin i.e. plants or animals or minerals. Cellulose is the main part of all plant fiber's structural components, but animal fibers containprotein.Due to the presence of more cellulose and cellulose micro fibrils, the alignment of bast fibers like flax, hemp, kenaf, jute and ramie become more in the perfect direction, so bast fibers are used in most of the composites in different sectors. The different effects of natural fibers depend on chemical arrangement and their structures, by which the types of fiber, conditions for growing, the time required for harvesting, methods of extraction, treatment process and storage ideas are determined. Over 5 days after optimum harvest time the reduction by 15% of strength has been seen[12]. Extraction of flax fibers manually has 20% higher strength than mechanically extracted fibers[13]. But glass fiber has high Strength and stiffness than naturalfibers.

Fiber length is the ratio of fiberlength and fiber diameter that influences the mechanical properties of green composites. In green composites having non lengthy fibers, the load (tensile) is transferred from the matrix to fiber through the interface. At the end point of the fiber, there is a null value for tensile_stressand that increases with the extension of the fiber. So, a length higher than the critical length (La) is required for fiber, which can break during the tensile loading of composites[14].Actually,fiber length must be higher than the La of a fiberfor reinforcing effectively in a composite. The critical fiber length can determine the surface of fracture since the average pull out a length of fibercannot be longer than half of the critical fiber length.Mathematical expression for La is

$$\frac{La}{d} = \frac{\sigma_f}{2\tau_i}$$

Where'd' is the diameter, σ_f is tensile_strength, and τ_i is interfacial_strength of the fiber.

It is found that La changes with the nature ofthe matrix,a process for treatment and weight of fiber.Lodha and Netravali in 2002 calculated the stress of fracture in green composites(ramie fiber and soy protein isolate), and it was shown that the fracture stress increased with the increment of length of fiber and weight of fiber. The averaged IFSS (fiber-matrix interfacial shear strength) was 29.8 MPa and the critical fiber length was 2.54 mm, evaluated by using the Microbond technique. But that biocomposite containing 10 wt % fiber and 5 mm fibers was not significantly reinforced with higher critical length.[15]

3.2. Matrix selection

One of the importantpartsof green compositesis bio derived matrices. The matrix keeps safe the fibers from environmental factors, erosion and also gives load to fibers. Now a day'sbiopolymers are used due to their light weight and capability of processing at very low temperatures, giving environmental safety and biodegradability[16].

As most of the natural fibers used for reinforcement in NFCs are not thermally stable at more than 200°C or they can be processed at a higher temperatures for a short time period so there are very limitedMatrices at the degradation point of natural fibers[17].It has been shown from different studies that PP has lower strength and stiffness with natural fibers than PLA[18].

Different types ofplants and most bacteriaare naturally produceda variety of compounds that have the capabillity to produce polymers.They have the metabolicmachinery that helps to synthesize to provide organic chemicals[19].Many precursors (lignocelluloses, cellulose, hemi_cellulose, lignin, ash, starch, chitosan, chitin, alginates, or polysaccharides) are used as the substrate to form applicable monomers for biopolymers. By polymerization, thebio derived monomers are converted to biopolymers with suitable techniques. By MyriantCompany succinic acid, was successfully synthesized fromcorn glucose andlingocelluloses.

Reverdia(2012) studied that Roquette and DSMItalyproduced about 10,000tonnes/year of succinic acid from glucose in Cassano Spinola(Italy), by using a recombinantE. coli. From Succinic acid there wereproduced many chemicals (1,4-butanediol, succino-nitrile, dimethyl succinate, 2-pyrrolidone, tetrahydrofuran,γ-butyrolactone, 4,4-bionolle,N-methyl-2-pyrrolidone, 1,4-di-aminobutane, succinimide)[20].

3.3. Interfacial strength

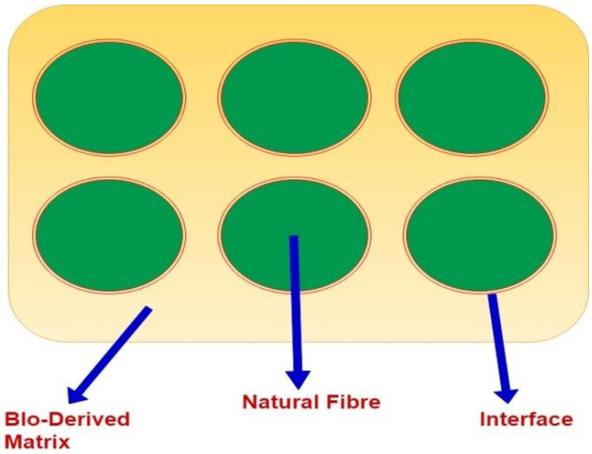

Fig -2. Interfacial bonding in between fiber and matrix,

The mechanical properties of composites also depend on the interfacial bonding between fiber and matrix, asby the interface, stress shifts in between matrix and fibers (Fig-2). For favorablereinforcement better interfacial bonding is required. Mostly, due to the hydrophobic nature of matrices and the hydrophilic nature of plant based fibers, there is limited interaction between them and forms poor interfacial bonding, which decreases themechanical behavior and low moisture resistance. The wettability of fiber also affects the mechanical behaviors like toughness, tensile and flexural strength of composites[21]. By applying appropriate physical and chemical actions the wettability of the fibercan increase whichenhances the interfacial strength[22-24]. The occurrence of interfacial bonding depends upon the activities and behaviors of mechanical interlocking, electrostatic and chemical bonding andbonding nature in inter_diffusion[25]. The interfacial strength is determined by the type and density of Chemical bonding. Chemical bonding takes place when a bond forms between the chemical groups present in the matrix and on the fiber surface. Chemical bonding is formed by the use of a coupling agent, whichplays a vital role in chemical bonding between fiber and matrix, as it behaves as a bridge between them. At the same interface simultaneously, there can be possible more than one type of bonding[26]. Carboxyl and hydroxyl groups are mostly used as coupling agents and due to the increase of these types of groups, enhance the interfacial bonding and surface polarity. Hence the chemical and physical activities help to increasesurface polarity,fiber roughness. Many physical and chemical properties are studied by researchers to increase the mechanical properties of NFCs.

By treatment of Alkali, some extra fibers (Hemicellulose, lignin, pectin, and fat)are removed from cellulose which improves roughness and area of surface, interfacial bonding, modifies the structure of cellulose and increase crystallinity[2728].

Esterification takes place by acetylation process where acetyl groups react with hydroxyl groups presenton the surface of fibers which increases interfacial_bonding, tensile_strength, and hydrophobicity[29], as well as structural and thermal stability and resistivity (fungal attack) in NFCs[30-32]. But more treatmentcauses harm to mechanical properties due to the degradation of cellulose and cracking of fibers[30].

Silanetreatment also provides a bridge between hydrophilic groups of the fiber and hydrophobic groups in the matrix.At first silane is treated with biofibers where hydrolysis of silane (alkoxy groups) in presence of water takes place to obtainSi–OH groups further which interacts with -OH groups present on the surface of fiber[3334]. In this process hydrogen bonding /covalent bonding generally occurs.

3.4. Fiber dispersion

Fiber dispersion is a method that influences the properties and behaviors of short fiber composites and other NFCs, generally having hydrophilic and hydrophobicfibers and matrices respectively[35]. The use of lengthy(longer) fibers can again enhance their capacity to form a composite. Betterfiber dispersion boosts the bonding in interface; reduces voids by surrounding fibersalong the matrix[36]. Parameters like temperature and pressure also affect dispersion.

3.5. Fiber orientation

The orientation of fiber affects more the mechanical behaviors of composites. Ifthere is a parallel alignment of the fibertakes place in the direction of the applied load can give better mechanical effects[37-39]. In the case of continuous synthetic fibers, it is easier to align properly than natural fibers. Some alignment can be possible in throughout injection moulding, which depends both on the viscosity of matrix and moulding design[40] .

For the best degrees of alignment in fibers, thelonger natural fiberis identified and keptby hand in sheets sealing with matrix to reduce porosity. By a spinning process which is a traditional process forfibers isalso employed to producea long yarn.

Recently, DSF (Dynamic sheet forming) process is used for fiber alignment in composites, which provides high level mechanical performance as compared with other techniques used for short fiber processing. This method is used to align fiber traditionally to produce paper. At the university of Waikato recently published about strengths (above 100 MPa) for discontinued(short) hemp as well as harakeke fiberalignment in PLA by using DSF.

3.6. Composite manufacturing

When a naturalfiber is reinforced with a matrix(resin) a biocomposite is formedwhich hasthe properties of the matrix and fibers that were used and biocompatibilityin nature. The matrices are used generallyin polymers obtained from renewable resources. It protects the fibers from environmental factors to reduce degradation and damage by holding thefibers together and helps to shift the tensile loads on them. As biocomposites have many applications in our day to day life as used for the production of different types of papers, clothes, rayon, silks cotton and applied in industrieslike automobile sector, coaches for railway, in aerospace, for constructions, and packing materials, the interest in production of biocomposites are growing rapidly as these are renewable, cheap, recyclable, and biodegradable[41-44].

The processes are involvedin the production of biocompositesare: pressing by machine,winding of filaments,pultrusion,extrusion,injection molding,molding by compression,molding by resin transfer, and sheet molding process.The in-situ polymerization process is used for nanofillers dispersion in monomers, which is escorted by solution polymerization or bulk polymerization.To find a better dispersion in polymer matrix the nanofillers are regularly changed by functional group which develops a good interaction between the nanofillers and polymers and give higher performances of final products [4546].Increasing melt and impact strength, thermal stability, permeability of biopolymers as well as reinforcing nanoparticlescan makebiocomposites retain original characteristics withbenign properties[47].

3.7. Porosity

If any void is formed during processing due to the insertion of air then porosity forms. The porosity forms due to low wettability andlow compatibility of fibers, hollow features like lumens within fibers or fiber bundles due to high pressure and temperature[48]. Porosity in NFCs is generally due tothe presence of more fiber content or more rapid compaction and also relieson fiber types and orientations.

4. Mechanical performance of natural fibers and composites

The physical properties of each naturalfiberplay an important role to measure different properties and in applications of NFCs. The physical properties like dimensions of fibers, fiberdefects, strength, crystallinity, inner structure, and discrepancyare very important to calculate mechanical performances in NFCs. With the stronger interface, there is an increase in efficiency of stress transfer to the fiber from the matrix. The change in natural fibers takes place throughphysical processes like stretching, thermal treatment and formation of hybrid long yarns. The physical processeshelp to modify the structural properties and properties of the fiber's surface and the mechanical bondingof polymers butdon't change the fiber'schemical structure.

Table-4. Physical Properties of some natural fibers and glass fiber

Fibers	Tensile_Strength(MPa)	Young's_modulus (GPa)	Elongationat brake(	Densit y (g/c

			%)	m^3)
Cotton[49]	287-587	5-13	7-8	1.5 – 1.6
Jute[50,51]	187-773	13-26.5	1.5-3.1	1.23
Flax[52]	345-1500	27-39	2.7-3.2	1.5
Hemp[5051]	580-1110	70	1.6-4.5	1.35
Ramie[5051]	400-938	61.4-128	2.0-4.0	1.44
Sisal[5051]	507-885	9.4-22	1.9-3.0	1.2
Coir[49]	175	4.0-6.0	30.0	1.2
Henequen[53]	430-570	10.1-16.3	3.7-5.9	1.2
Banana[5051]	529-914	8-32	3-10	1.35
Bamboo[54]	391-1000	11-30	2	0.8 – 1.4
Oil palm[49]	248	3.2	14	0.7 – 1.55
Kenaf[5051]	295 -930	53	2.7 - 6.9	1.2
Curaua[52]	500–1100	11.8–30	3.7–4.3	1.4
Glass fiber[52]	2000–3500	70–73	2.5-3.7	2.55

Table-5. Study of Some composites mechanical behaviour:

Composites	Elongation to break (%)	Tensile strength(MPa)	Young modulus(GPa)	Processing
Starch + jute(30 %)[55]	2 ± 0.2	26.3 ± 0.55	2.5 ± 0.23	Injection molding
PLA + jute(30 %)[56]	1.8	81.9±2.9	9.6 ± 0.36	Injection molding
PHBV + jute(30 %)[57]	0.8	35.2 ± 1.3	7 ± 0.26	Injection molding
PLLA + flax(30 %)[58]	2.3 ± 0.2	98 ± 12	9.5 ± 0.5	Compression molding(Film stacking)

PHB + flax(30 %)[58]	7 ± 1.5	40 ± 2.5	4.7 ± 0.3	Compression molding (Film stacking)
PLA + flax(30 %)[59]	1 ± 0.2	53 ± 3.1	8.3 ± 0.6	Twin screw extruder and compression molding
PP + fiberglass(30%) [52]	3.01 ± 0.22	82.8 ± 4.0	4.62 ± 0.11	Compression molding

4.1. Advantages of natural fiber based Green composite

Table-4 is the study of mechanical values for natural fibers and glass fibers.In table-4 we can see most of the natural fibers are very closestto the middle of each certain range. From this table, wecan differentiate mechanical strength values between the glass andnatural fibers collected from different research paper's stiffness values &density values. From the Table-4we can assume that most of the natural fibers can compete with glass fibers, generally jute, flax, hemp,sisal, chicken feather fiber, kenaf, bamboo etc.The most advantage of natural fibers are low cost, light weight, easily renewable, lower energy consumption, less investment, easier to handle and process, better specific mechanical behaviors, recyclable, and good thermal insulation as compared to glass fibers[60]. Kimet al.[61]observed that at large strain rates,NFCs had very good energy absorption capacity as compared toglass fiber based composites. For structural based applications bast fibers show best properties; as flax has the capacity of perfect potential combination, high strength at very less cost as well as lightweight with high stiffness, Jute is also a very commonfiber,but lesserstrong and stiff as compared to flax[62].Natural fibers arecheaper with low densities than glass fibers, but the strength of natural fiber isremarkably low. But due to better specific modulus values, natural fibers prefer for implementation in different sectors, in which place the stiffness and weight offiber are important concerns[62]. The renewed interest in natural fiber composites is emerging as a viable alternative to glass-fiber reinforced polymer (GFRP) composites for many reasons. As NFCs are 25% to 35% stronger than glass fiber with the same weight and also the same execution capacity for a lesser weight. In automotive materials, NFCs minimize the component mass and reduce the energy consumption by 70- 80% during the production of composites and reduces machinery maintenance, and production costs by up to 25-30%. NFCs have no more brittle nature as compared to glass fiber composites, which is a very specific requirement in the compartment ofpassenger transport. Cultivation of natural fiberrequiressolar energy, but glass and glass fiber production requiresfossil fuels/ electrical fuels. So, emissions of a pollutant from glass fiber production are usually more than natural fiber production.

From Table-5, we can compare the mechanical properties of green composites with glass fiber based composites and observe the better mechanical values in green composites. From the studies of Oksman et. al.[63]produced PLA/flax green composites andemphasized the properties of PLA/flax composites than mostly used PP/flax composites. From the study, they observed that the mechanical properties of PLA/flax green composites had 50% more efficiency than PP/flaxcomposites.

Bio derived matrices and natural fiber composites were prepared and examined and it was observed that these had a very positive impact regarding environmental benefits,better mechanical effects, and very low weight[64-70].

Vilaseca et al.[71]have fabricated starch with jute strands by the method of injection moulding to form green composites. They comparedthemechanical properties of various percentage compositions of alkali treated and untreated jute strands. The tensile strength of alkali untreatedjute in the above greencomposites, it was observed in the increment of tensile strength with the fiber quantity (10, 20, and 30%(w/w)) and also for alkali treated jutestrands in the abovegreen composite, it was observed the increase in stiffness and strength with increase in fiber contents. There also observed that the humidity absorbance capacity of the green composite is very low (tested for 72 days in the openair).

Averous et. al.[72], they prepared TPS composites from leaf and wood cellulose fibers and bio matrix(derived from wheat starch by applying water/glycerol for plasticization). It was observed that at 30°c of transition temperature, there was an increase of mechanical behaviors.

There are certain observations and experiments were done about the applications of celluloseesters as matrix in different biocomposites[73-77]. Many of the natural fiber and cellulose ester based composites were prepared by different methods (injectionmoulding, extrusion, blow and rotation moulding)and the temperature 180 °c to 240 °crequired for preparation of cellulose esters and Tg values are 140 °c to 190 °c for the cellulose esters many plastic applications[78].

5. Applications

Green composites have very favorable advantages for different companies, due to the gradually diminishing in petroleum reservoirs. So, green composites are used widely in many sectors like automotive parts, construction, wind turbine blades, biomedical applications, food packaging, and others, etc(Fig-3).

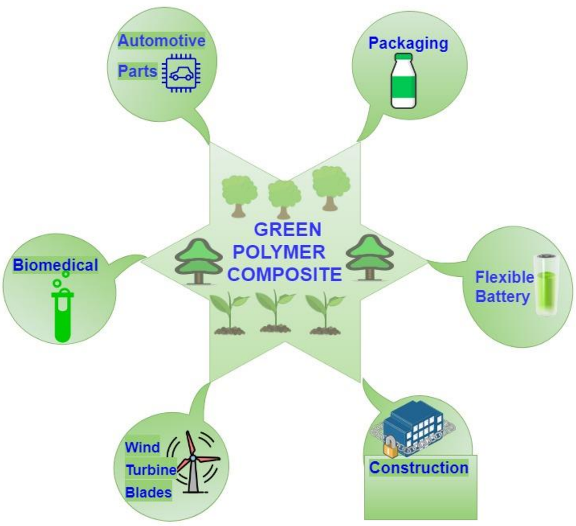

Fig-3. Different applications of Green polymer composites

- Shih et al.[79], in thisresearch the fiber basedreplaceable materials were reused,and prepared green compositesto manage wastes in many countries.

- Green composites are also used in a wristwatch (Patch) made frombiodegradable paper[80], other green composites are also prepared from disposable_chopsticks[79], and lignin based carbon fiber[81].
- Green composites play an important role in tissue engineering, as drugs carrier and bone scaffolds in the biomedical applications[82-85].
- Biodegradable materials such as PLLA, cellulose,and PDLLA are used withbiopolymers like PLGA, PLA, PEG, and chitosan for the formation of different useful green composites[86].
- As chitin-derived chitosanis free from toxicity, and hasless processing impact onthe environment, so it is used more in different sectors[8788].
- Biodegradability food packaging system is a demanding issue in the European countries[89]. So there are many biopolymers and biopolymer based nano composite materials that are used forfood packaging[90]. Mainly materials used for food packaging are derived from the composites like polysaccharide and starch based; polysaccharide and cellulose based, protein based, PHA based, and PLA based.
- Toyota has prepared 1st fully (100%) bio derived automotive parts(likeRaum spare wheel cover) in the world from kenaf/PLA non-woven sheets by press-mould process.
- By John Deere, Soybean and natural fiber based composites (by using RIM process) are usedto prepare body panels and cab roofs for hay balers which are 25% lightweight. More recently, EcoTechnilin prepared a sandwich panel composite fromnonwoven flax and bioresinswith a honeycomb core of paperin the Jaguar F-type (for load floor)[91].
- The Ford Motor Company usedbio composites made from natural fiber and wheat straw in 2010 and by using this they can reduce 9 metric tons of petroleum usage and 13.5 Mt/yearemission of CO.
- For injected instruments and door panels, consoles are prepared to form biomat (hemp/ PBS) by Faurecia.
- Coconut fibers and rubber latex composites are used in the A-class model of Mercedes Benz for seats[92]. A recent concept for a car is aroused by Forest and Biomaterials supplier, Finland and Applied Sciences, HM University, Helsinki who have developed the major replacement of plastic parts with highly durable and safe qualitative biomaterials, in the place of UPS Formi and UPM Grada, were used to manufacture the passenger compartment floor, center console, display panel cover, door panels, front mask, dashboard, and interior panels. It was observed that the car made from these materials is closely 150 kg low weight and lower fuel consumption capacitythan its counterparts.[93].

- In 2013, the 100% biocomposite based building Facade clad from hemp fiber and a bio based resin, was established(gas receiving station Netherlands)[94 95].
- Only natural fibers can also be used in insulation, roofing, and geo_textiles. Hemp sliverscan deliver structure and very good insulation behaviors, which is made from wastes of hemp fiber andare used as hemp lime (blocks or sheets) onto walls. In the Adnams Brewery warehouse construction, hemp lime was used in Suffolk, United Kingdom. By using the hemp lime, it savesalmost £40,000/year by keeping constant temperature of 16°C except heater and air coolers[94]. Due to high carbon capture capability hemp fiber fleece are used as insulating materialin Germany[94]. 35,000 protective blocksmade from GreenGran granules (natural fiber-reinforced biopolymers PLA and PHB) were placed on riverbanks and dams to prevent riverbank erosion [96].
- Since the year of 2016, China used ahundred sets of 800KW bamboo wind turbine blades as these have large wind strengthand good stiffness and toughness and reduced cost of 15% compared toglass fiber basedwind turbine blade [97].

6. Conclusion

To reduce the petroleum based materials and save the environment the research and development for biomaterials are increased. Due to the low cost and high durability of biocomposite, these can be used in many sectors of the world. The best advantage of biocomposites is product purities, renewability, and cheap.

So, nowadays Natural Fiber reinforced biocomposites have made an importance place in different sectors due to high strength-to-weight ratio and can solve the problem of no recycling or no biodegradability of other materials after their lifetime, due to which environmental bad impacts are shown as dumping is the main problem in today’s life. So, naturalfibers and biocomposite materials have considerable environmental advantages due tothe biodegradability nature, lowcost, and high mechanical properties, of these materials. For improvement of moisture resistance, higher mechanical properties and fire retardant capacity further research is required to save the world from the conversion of dustbin.

GO GREEN AND MAKE GREEN

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