Composites: Types, Method of Preparation and Application as An Emerging Tool for Environmental Remediation

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Abstract
Pollution is one of the major problems in most of the developing and developed countries. Water pollution remains a source of constant concern for environmentalists. With the growth of industrialization and globalization this issue is rising day by day. Several types of methods and materials have been used to avoid these problems, but often the methods proved to be useless in the absence of proper method and materials. In order to streamline these methods such as ion exchange, membrane filtration and adsorption, continuous new types of effort and materials are being made. In the material used so far, the best features of composite materials have come out, which has opened a new door in the field of treatment technologies. Composite is made up of different types of material having unique properties. The combination of different desired material is required to obtain the desired results in the composites thus resultant composites prove to be highly advance, unique and beneficial. In this chapter, we have discussed the different types of composite materials, and their preparation strategies and applications. The detail study on matrix and reinforced material based composites, and green composites have been conducted. This chapter will definitely be the preferred choice of environmentalists.

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1.1 Introduction

Concerned with the problems of the environment, environmental engineers are developing the solutions by using the principles of biology and chemistry. Most common issues on which the engineers are focussed currently are disposal and recycling of the waste materials, air and water pollution, controlling the public health issues, removal of polluting substances from the surroundings, harmful effects caused by acid rain, global warming, auto mobile emissions, depletion of ozone layer etc. [1–3]. These effect the ecosystem which ultimately leads to human health problems and may sometimes even prove fatal. One such matter rising at the global level is water pollution [4–7]. Water which is a very precious resource is useful for us in a number of ways but its quality is degrading day by day. Major sources of water pollution include industrial, municipal, agricultural, natural, storm water, landfill, underground storage tank etc. [8–11]. Among them industrial waste plays a major role in polluting water bodies that release dyes and harmful metal ions [12, 13]. Human health is affected to a great extent and sometimes even proves fatal [14–16].

In the present times many types of materials or combination of material are being used for reducing the environmental pollution. Composites are one such type.

Composites can be defined as “artificially made material made by the combination of two or more material that is different in the properties of its constituent”. Both the constituents are chemically different from each other and are separated by an interface [16–19]. Composites are different from that of conventional materials because of their superior properties [17–20]. Composites contain a continuous phase called Matrix and dispersed or discontinuous phase called Reinforcement or reinforcing material. Properties of the particles get changed when the size of the particles is below their critical size. As dimensions reach the nanometre level, the interactions at phase interfaces become largely improved, and this plays an important part in enhancing
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Materials properties [21]. Matrix can be made from polymer (synthetic or natural), metal, ceramics and resins while the reinforcement are the nanoparticles, fibers, filled, whiskers, flakes, particulates, directionally solidified eutectics. Engineers and scientist are trying to make composites having better and better properties by combining different metals, alloys, ceramics, and reinforcement material. As a result of which composites are used for a wide range of applications.

With the current advancements, composites are being replaced by the nanocomposites. A nanocomposite can be defined as a composite material formed by the combination of two or more components in which one component phase have nanoscale dimensions (0D,1D,2D) that is around $10^{-9}$ m. This nanometre sized materials are dispersed/embedded in the matrix of a polymer, metal or ceramic. It is a multiphase solid material. Nanocomposites are very much different from conventional composites for the exceptionally high surface to volume ratio of the reinforcing material and/or its exceptionally high accept ratio.

Following parameters affect their properties like process used in the synthesis, material of the matrix which can exhibit nanoscale dimensions, loading, modification of the surface of nanoparticles, dispersion degree, size, shape and orientation of the nanoscale reinforcement phase and interaction between the matrix and the reinforcements. Due to the distinct properties of the constituents and inhomogeneous distribution of the reinforcement material these nanocomposites have direction dependent properties which we called anisotropy [22]. Interphase plays a very important role in the properties of the composites which tells us about the bonding between matrix and reinforcement material. Elasticity, strength, chemical potential varies from composites to composites since the preparation involves different types of reinforcement and matrices. But as the discontinuity in the above parameters occurs between the reinforcement and matrix, then not only by the medium of transition but also the matrix will create a chemical compound at interface due to the discontinuity in chemical potential [23]. Interfacial bonding is there between interface and matrix. This bonding will be strong and weak depending on the type of composites containing phases. Like in PMCs and MMCs strong bonding is chosen while in case of CMCs weak bonding will be chosen [24].
While synthesizing the composites/nanocomposites following points should be kept in mind:

a) Matrix selection

i. Amount of the polymeric matrix material.
ii. Properties include aspect ratio, chemical nature, purity, distribution, orientation and geometry.
iii. Interaction between the two i.e. adhesion [25].

b) Reinforcement selection

i. The basic mechanical properties of the fiber itself.
ii. The surface interaction of fiber and resin (the ‘interface’).
iii. The amount of fiber in the composite (‘Fiber Volume Fraction’).
iv. The orientation of the fibers in the composite [26].

1.2 Classification Based on Matrix

Based on the type of matrix composites can be classified as (Figure 1.1):

![Classification based on matrix.](image-url)
1.2.1 Metal Matrix Composites (MMC)

Composites consisting of a matrix of a ductile metal (aluminium, magnesium, iron, cobalt, copper) or alloys which constitute the continuous phase in which nanoparticles are implanted as a reinforcement material called dispersed phase. These metals are of low density while the ceramic reinforcements like silicon carbide (SiC), aluminium oxide (Al$_2$O$_3$) or minerals like mica, graphite etc. The continuous phase results in change in the physical, chemical and mechanical properties of composites than those of matrix alone. Some common metal matrix nanocomposites include Ag/Au, Ni/PSZ [27], Ni/YSZ [28], Cu/Nb, Al/SiC [29].

While, they are much better than polymer composites in the properties like high strength, fracture toughness and stiffness, capability of tolerating high temperature conditions in the corrosive environment. The nanoparticles are having the following characteristics as a good reinforcement material:

i. Non-reactiveness with matrix material.
ii. Stability over a range of temperatures.
iii. For high modulus matrix, high modulus NPs.

The matrix of the composites itself alone are not having high strength and toughness but when nanoparticles are added they cause the difficulty in the dislocation movement which results in the better mechanical properties.

1.2.2 Methods for Synthesizing Metal-Matrix Composites

Various methods for synthesizing metal matrix complex are (Figure 1.2):

a) Spray pyrolysis

The liquid matrix material gets atomize by an atomizer to produce a mist which is then passed to a substrate and a high velocity carrier gas loading the substrate material.
b) Liquid metal infiltration

Infiltration means permeation of a liquid into something by filtration. Here the molten metal matrix after the thermal treatment infiltrated into a porous preform.

Example: Silicon carbide (SiC) matrix composites - The molten silicon infiltrated into the carbon (C) microporous preform by the capillary action when the molten temperature of silicon exceeds its melting point [30].

c) Vapor techniques

i) Chemical Vapor Deposition

A CVD apparatus has the following components gas delivery system, reactor chamber, energy source, substrate loading mechanism, vacuum system, exhaust system, process control equipment, and exhaust treatment system.

This method involves the deposition of the material in gaseous form (which will get at their ambient temperature) onto a substrate after passing through a reaction chamber. The substrate is heated previously. After it comes in contact with previously heated substrate a chemical reaction will take place and material is deposited on or near the solid surface. This method is versatile in nature, it can be used for the fabrication of
different metallic or ceramic composites. Also, a highly purified product will be achieved since the impurities are removed by distillation techniques from the gaseous reactants.

ii) Physical Vapor Deposition
Most common PVD process (Figure 1.3) are sputtering and evaporation. Sputtering is a plasma assisted technique in which a source target after bombardment through the accelerated gaseous ions creating the vapors.

The evaporation involves the production of vapors by heating the material in vacuum. PVD involves the condensation then evaporation and finally go back to condensation phase of a material. After the consolidation of the nanocomposites, supersaturation of the vapor phase occurs in an inert atmosphere so as to promote the metal nanoparticles condensation. This method is used to deposit thin layers of material in nm range.

![Figure 1.3](image) Apparatus of physical vapor deposition.
d) Rapid solidification
   Rapid solidification means rapid liquid state quenching. Products obtained by this process are powder, flakes, ribbons, wires and foils. Here the molten metal infiltrated a preform of fibers or particles until both are completely melt. This molten alloy is then freezing in the inter spaces of the fiber and form the composites.

   Example: Cast iron and aluminium silicon alloys [31].

e) Stir casting
   It is one of the simplest methods. The metal matrix gets a molten form by heating it into a furnace, then reinforcement material is dispersed into the molten matrix which is followed by mechanical stirring. So that the mixture will be completely mixed and we get a suitable dispersion. Finally, the dispersion gets solidified in appropriate conditions.

f) Chemical methods [32]
   i) Colloidal Methods
   ii) Sol Gel Methods

   It involves the two basic components for preparing composites. First a sol and then gel. Whole process involves the hydrolysis and condensation of the matrix and reinforcement dispersion mixture. After chemical reactions the sol gets converted into a gel. Further process involves the heating treatment in the gel gets converted into oxides as final material which results in the formation of composites. A large difference in structural properties is achieved according to the change of temperature.

   Example: Fe/Au-containing nanocomposite [33].
1.2.3 Bonding in Metal Matrix Composites

In MMC interface i.e. bonding between metal matrix (primary phase) and reinforcement (secondary phase) is one of the following (Figure 1.4a–c):

**Figure 1.4a** Direct bonding between primary and secondary phase.

**Figure 1.4b** Addition of third material to bond the primary phases.

**Figure 1.4c** Formation of inter phase by solution of primary and secondary at inter phases at their boundary.
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Types of Interfacial bonding at interface:

i. Mechanical bonding depends on the roughness degree of the fiber.
ii. Chemical bonding occurs between the chemical groups of the matrix and reinforcement and their compatibility.
iii. Electrostatic bonding involve interaction between oppositely charged surface of matrix and reinforcement.
iv. Reaction or inter-diffusion bonding.

1.2.4 Applications of Metal Matrix Composites

i. Pushrod i.e. used in automobile application is made from aluminium metal matrix composite. It is highly used as this composite is having attractive physical, mechanical and elastic properties [34].

ii. Reinforced MMC are light in weight so they are used as a component of aircraft and helicopters.

iii. Al/SiC/fly ash composites used for designing of various components in automotive sector because of great tensile strength and hardness as compared to unreinforced aluminium [35].

iv. Al/SiC/B4C composites are preferred for heavy duty vehicles and high wear resistance applications. While comparing to single ceramic reinforced composites these possessing greater hardness and toughness it is found [35].

v. Carbon-carbon composites which are used in braking system, refractory material etc.

1.3 Polymer Matrix Composites

Composites consist of a matrix of polymer such as homopolymer, copolymer, block copolymer, unsaturated polyester, epoxy, polycarbonate, polyvinylchloride, nylon, polystyrenes or polymer blends being dispersed with fibers, whiskers, platelets or particles, glass, carbon,
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steel, one-dimensional (nanotubes and fibers), two-dimensional (layered materials like clay) or three-dimensional (spherical particles). So, the continuous phase comprises the matrix while the discontinuous phase is reinforcement. In the application in which the polymer nanocomposites are employed the choice depends on the type of reinforcement. The properties of nanocomposites are entirely affected by the nanoparticles which are used. This is called as nano-effect [36]. Nanoparticles surface area, surface energy and type of geometry effect the matrix completely in terms of strength. Over all the properties of the composites depend on these nanosized reinforcements. Bond between matrix and the reinforcement are weak intermolecular force but chemical bond also exists if the reinforcement is dispersed at an atomic or molecular level.

The matrices possess the following physical and chemical properties:

i. High elastic stiffness and strength with a small concentration of nano additives

ii. Barrier resistance

iii. Wear resistance

iv. Flame retardancy

v. Clay minerals (montmorillonite, saponite, hectorite etc) added as filler materials in polymer matrix for obtaining high strength and hardness.

vi. Magnetic, electrical and optical properties.

vii. Enhanced thermal stability

viii. Polymer resins as reinforcement produces a dramatic improvement in their biodegradability.

ix. Hydrophobicity to hydrophilicity

x. Insulators to semiconductors to conductors

One of the most striking features of the polymer matrix is that they are highly porous and nanoparticles due to their high surface area resulting into the larger area of matrix is in nanoparticles region. As a result, gradual transition occurs in physical and chemical properties. In order to form a better and useful composites two criteria should be kept in mind. Firstly, the polymer matrix and reinforcement interaction must be very efficient. Secondly in the matrix,
dispersion of nanoparticles should be very effective so the processing is decided [37].

1.3.1 Classification of Polymer Matrix Composites

i. Thermoplastic Matrix Polymer Composites

They comprise a matrix of thermoplastic polymers (polyethylene, polystyrene, polyamides, nylon polypropylene) in which reinforcement are dispersed. Thermoplastic polymers are linear or branched polymers or 2D structures in which chains of molecules are not interconnected to one another. The individual molecules have linear structure with no chemical linkage between them. They are held together by weak secondary bond (intermolecular force such as Vander Waal and hydrogen forces). These polymers can change their shape and melt on heating and become hard on cooling. So, recycling can be done without affecting the properties.

The processing methods used for such polymers are injection moulding, film stacking, diaphragm forming and thermoplastic tape lying.

ii. Thermosets Matrix Polymer Composites

They comprise a matrix of thermoset polymers (epoxy, polyesters, phenolic polyamide resins) in which different types of fillers are dispersed (Carbon Nanofibers (CNFs), Montmorillonite organoclays (MMT), Metallic nanoparticles, Carbon nanotubes (CNTs), ceramics). These polymers are heavenly cross-linked, having a 3D structure. They do not melt and cannot be remoulded but will decompose on heating. One of the forms of chopped fiber composites offer a wide range of applications. These are better as compared to thermoplastic in rigidity and improved mechanical properties. Processing methods includes hand layup, spray layup techniques, filament winding, pultrusion, resin transfer moulding and autoclave moulding.
1.3.2 Methods for Synthesizing of Polymer Composites

Various methods for synthesizing of polymer composites are listed below (Figure 1.5):

i) Intercalation of the Polymer/Pre-Polymer from Solution

Plate-like nanofillers are dispersed in the polymer matrix. This method is suitable for layered silicates composites. Silicates reinforcement is penetrating into the matrix, depending upon the degree of penetration composites structure ranging from intercalated to exfoliated types. Polymer is dissolved in co-solvent while plate-like nanofillers in solvent. Both the solutions are mixed together and polymer chains displaced the nano-platelet solvent and will intercalate in it. Thus, leading to the formation of polymer layered silicate composites.

Figure 1.5 Methods for synthesizing of polymer composites.
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Examples: Clay with PCL, PLA, HDPE, PEO, PVA, PVP, PVA, etc. [38,39, 40–46].

ii) In-Situ Intercalative Polymerization
In this method the nanofillers that are used as a reinforcement being dispersed in the monomer solution and the fillers get swollen. Polymerization of the resulting solution is done by heat, radiation or by organic initiator.
Examples includes montmorillonite with N6/PCL/PMMA/PU/Epoxy [47–51].

iii) Melt Intercalation
Softening temperature of polymer is the key parameter here. In this method both the nanofillers (clays) and the polymer matrix are mixed together above softening temperature of the polymer. Annealing of the solution mixture is done either statistically or under shear. Due to which the monomers are being dispersed into the layers of the host material.
Examples: Montmorillonite with PS/PEO/PP/PVP, Clay-PVPH [52–56].

iv) Direct Mixture of Polymer and Particulates
One of the simplest and easiest method of synthesizing polymer matrix composite involves the direct mixing of the polymer and fiber when the polymer melts above its glass transition temperature this method is called melt compounding method. Second method involves the mixing of both polymer and fiber in a solvent which is called solvent method [57].

v) Template Synthesis
Used for the synthesis of LDH nanocomposites. This method involves the dissolving of both polymer matrix and clay layers in an aqueous solvent. Nucleation and growth of clay layers takes place when the polymers get trapped inside the layers at high temperature. This polymer is water soluble, acts as a source of template [58–62].
Examples: Hectorite with PVPR, HPMC, PAN, PDDA, PANI.
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vi) **In-Situ Polymerization**
In this method reinforcement is dispersed in the polymer matrix (which is the monomer having low molecular weight, a precursor) solution, when the mixture of reinforcement and polymer matrix gets homogenised, an appropriate catalyst is added for the polymerization process.

Examples: PET/CaCO₃, Epoxy vinyl ester/Fe₃O₄; Epoxy vinyl ester/γ-Fe₂O₃; Poly (acrylic acid) (PAA)/Ag, PAA/Ni and PAA/Cu AgNO₃, NiSO₄ and CuSO₄ [63–66].

vii) **Sol-Gel Process**
This method is also known as chemical solution deposition. By using this method for synthesizing metal oxide nanocomposites, the texture and surface properties can be easily controlled. It involves three steps:

- **Hydrolysis**: It involves the production of hydroxide solution of reinforcement and monomer which is called “sol”.
- **Condensation**: It involves the formation of a 3D interconnected network formed by the polymerization reaction and the hydrolysis.
- **Drying**: This process involves drying of gel and formed composites [67].

Examples: 2-hydroxyethyl acrylate (HEA)/SiO₂, Polyimide/SiO₂, polyimide/silica, polyethylacrylate/SiO₂, PMMA/SiO₂, polycarbonate/SiO₂ and poly (amide-imide)/TiO₂ [68–71].

### 1.3.3 Bonding in Polymer Matrix Composites

Thermosetting polymers have epoxy, polyesters, phenolic polyamide resins which are polar in nature and have surface energy values which provide good wetting to the reinforcement via the intrinsic adhesive adsorption mechanism. The inter-atomic and intermolecular forces like dispersion forces, primary chemical (e.g. covalent bonding)
forces, dipole forces and hydrogen bond forces are acting in between the adhesive/composite's interphase. While in case of thermoplastic polymers (polyethylene, polystyrene, polyamides, nylon polypropylene) surface free energy have lower values, therefore bonding in these are quite difficult. So engineers are using special adhesive materials after the pre-treatment of the composites materials.

1.3.4 Applications of Polymer Matrix Composites

i. In Aerospace industry, carbon fibers are extensively used as reinforcement materials.
ii. As polymers are less dense consisting of light carbon and hydrogen atoms they are used as structural components and in applications which have the need of lightweight materials such as automobile, defence, aerospace and electronics.

1.4 Ceramic Matrix Composites

Ceramic a word derived from a Greek word “keramikos” meaning pottery. Ceramics are the inorganic and non-metallic solid material exhibiting strong ionic and to some extent covalent bonding, having crystalline nature. They can tolerate high temperature conditions but on mechanical and thermal loading catastrophic failure occurs. So, lack of toughness is one of the main reasons that these are not used in structural applications. So, ceramic matrix composites have been synthesized now a day for improving the toughness. They are best considered for high temperature conditions [72].

Ceramic matrix composites are the composites consisting of ceramic matrix reinforced with different kinds of reinforcement, thus forming a ceramic fiber reinforced ceramic material.

Their main applications are restricted due to their brittle behavior. Due to the fact that ceramic materials have superior properties they are used both as matrix material and reinforcement in many industrial applications. Main function of reinforcement is not only to provide the toughness by blocking the dislocation movement and act as a barrier for crack propagation but also improved properties such as electrical
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and thermal conductivity, thermal expansion, hardness, thermal shock resistance, high corrosion resistance.

For improving the strength, particle strengthening and fiber-reinforcement have been utilized. Reinforcement of ceramic matrix is done by either continuous long fiber or discontinuous short fibers. One of the main disadvantages of reinforcing ceramic matrix with short fibers is catastrophic as compared to long discontinuous fiber. Examples of short fiber composites: aluminium nitride (AlN), titanium boride (TiB₂), oxide (alumina) or non-oxide (silicon carbide) ceramic matrix reinforced by the whiskers of silicon carbide (SiC), zirconium oxide (ZrO₂).

Example of long discontinuous fiber: Silicon carbide matrix composites, mullite (alumina and alumina-silica (mullite) matrix composites, carbon-carbon composites [73].

1.4.1 Methods for Synthesizing Ceramic Matrix Composites

Various methods for synthesizing Ceramic Matrix Composites given in Figure 1.6:

Figure 1.6 Methods for synthesizing of ceramic matrix composites.
1.4.2 **Advantage of Ceramic Matrix Composites**

i. Non-catastrophic failure
ii. Higher chemical stability
iii. Corrosion resistance
iv. Wear resistance
v. Do not react with chemicals
vi. It can withstand high temperature [73]

1.4.3 **Disadvantages of Ceramic Matrix Composites**

i. CMC requires high temperature for processing that can be employed for temperature reinforcement.
ii. High temperature is required during processing process which results in complex manufacturing thus resulting in complexity and expensive materials.

1.4.4 **Applications of Ceramic Matrix Composites**

i. Silicon carbide whisker-reinforced $\text{Al}_2\text{O}_3$ and $\text{Si}_3\text{N}_4$ are used in cutting tool.
ii. Ceramic matrix composites used as industrial materials such as high alloy steels and refractory metals.
iii. Discontinuous reinforced ceramics are being used in chute liners.
iv. Silicon carbide whisker-reinforced $\text{Al}_2\text{O}_3$ and $\text{Si}_3\text{N}_4$ used in Cutting tools.
v. Aerospace
vi. Jet engine
vii. Components for burners, flame holders.
viii. Components for high temperature gas turbines such as turbine blade, combustion chambers.
ix. Hot fluid channel
x. In Energy sector silicon carbide continuous fiber reinforced matrix composites for nuclear applications are used due to high temperature strength
xi. Industrial uses of CMCs include furnace materials, energy conversion systems, gas turbines and heat engines.
1.5 Classification Based on Reinforcement

Based on reinforcement composites can be classified as (Figure 1.7):

1.5.1 Fiber-Reinforced Composites

Composites having the dispersed phase is in the form of fibers are classified as whiskers, fibers and wires on the basis of diameter. Fibers are of glass fibers, silicon carbide fibers, high silica and quartz fibers, alumina fibers, metal fibers and wires, graphite fibers, boron fibers, aramid fibers and multiphase fibers are used. Glass fibers, is again classified into E-glass, A-glass, R-glass etc. [74]. They are further classified as:

- Continuous (aligned)
- Discontinuous (short)-Aligned and randomly oriented

The characteristic properties of fiber-reinforced composites depend on fiber length (long and short), fiber orientations (continuous and aligned, discontinuous and aligned, and discontinuous and randomly oriented fiber reinforced composites) fiber shape, composition, concentration, fiber phase and matrix phase. These parameters effect the specific strength i.e. ratios of tensile strength to specific gravity and specific modulus i.e. ratio of modulus of elasticity to specific gravity.

Matrix phase of fiber reinforced composites are made from ceramic, polymer or metal which are discussed above.

![Figure 1.7](image_url) Classification based on reinforcement.
1.5.2 Particle Reinforced Composites

For a composite to be good in stiffness and strength there must be good interaction and bonding in between the composites constituting material i.e. matrix and reinforcement. An interaction at atomic level is one of the reasons of high strength. Dispersion strengthened composites include the extremely small particles that are dispersed to a great extent and well bonded in matrix material thus, provide great strength. They are further classified as:

- Large-particle
- Dispersion-strengthened composites

Large particle composites contain larger size particles that are not well dispersed like smaller ones. Reinforcement action causes the enhancement in mechanical properties.

1.5.3 Structural Reinforced Composites

They are further classified as:

- Laminated composites

Wood considered as the best example for describing laminated composites. Laminated composites are 2D-dimensional sheets of material containing a layer of materials bonded together. Stacking and cementing of the layers in a particular direction, length of the layer that are bonded with each other tells the degree of strength. Laminated structure of the modern times having complex laminated structure, metal-plastic laminates (metal-plastic, vinyl-metal laminates) are the examples. Processing methods include adhesive bonding, pre-coating or cladding methods.

- Clad or Sandwich composites

Two separate sheets bonded by an adhesive thicker core. Source of stiffness and strength in the composite are the sheets parts which are made up of aluminium alloys, titanium, steel and fiber reinforced plastics. Thickness of the sheets kept in such a way that it
can withstand the stresses that are resulting from the loading. Core present in between the sheets serves many functions:

i) Act as source of support in between the sheets  
ii) Providing stress and stiffness  
iii) Capable of withstanding transverse stress.

These composites are used in a number of ways like roofs, wall of building floors.

1.6 Recent Advancement in Composites

Green composites are gaining attention at global scale because of environmental awareness, reductions in usage of oil-based resource, consumption of renewable and biodegradable resources during processing. They are not only being used in engineering applications but are also gaining importance at economical scale.

Green composites are composites of natural resins/polymers. The biodegradable material constitutes the continuous phase embedded with plant fibers as reinforcement or discontinuous phase. These plant fibers act as a source of mechanical strength. Most commonly used polymers for green composites are polylactic acid, polyhydroxybutyrate, starch etc. Examples: Kevlar/SPC based resin, Cellulose/SPC based resin.

Natural fibers may be classified into two broad categories:

- Non-wood fibers:  
  They are of following types - bast fibers, leaf fibers, seed fibers, fruit fibers and stalk fibers.
- Wood fibers:  
  They are of following types:  
  i) Hardwood fibers-fibers from aspen and birch  
  ii) Soft wood fibers-fibers from pines, spruces, larches

Biodegradable polymers can be classified on the basis of their origin:

i. Natural  
ii. Synthetic
1.6.1 **Methods for Synthesizing Green Composites**

Some of the important methods for synthesizing green composites are listed in (Figure 1.8).

1.6.2 **Advantages and Disadvantages of Green Composites over Traditional Composites**

Despite green composites been proven having advantages over traditional composites, they do have certain drawbacks that need to be worked upon.

1.6.3 **Applications of Green Composites**

i. Used in aircrafts and ships because of the light weight

ii. In mobile phone for example composites of kenaf and PLA for reducing CO₂ emissions.

iii. Banana fibers and its composites used as interior decoration material

iv. Composites of plant derived fiber and crop-derived plastic use for solution of uncertainty of petroleum supply

v. In spare tire cover, circuit boards PLA/kenaf fiber composites are used.
1.7 **Advantages of Composites**

i. Wide variety of methods, different types of reinforcement and matrix material offers the use of composites in wide range of applications.

ii. Composites offer excellent resistance to corrosion, chemical attacks, impact damage and heat.

iii. Composites are able to withstand high temperature for carbon-carbon composite used for designing leading edges of the wings in space shuttle can retain its properties even at 2000°C.

iv. Properties are greatly improved that include high strength or stiffness to weight ratio, improved torsional stiffness, dimensional stability, improved weatherability, improved friction and wear properties, heat sink properties, improved dent resistance, improved reliability for fewer structural failures.

v. Cost of production is low.

1.8 **Disadvantages of Composites**

Although possessing many advantages composite materials have some of the draw backs such as (Figure 1.9):

i. Fabrication and material cost is high for example composites synthesized from biodegradable components are too expensive.

ii. Composite materials are difficult to repair, more brittle and easily damaged.

iii. Isotropic a word used in metals while for non-metals anisotropic. In composites anisotropy exists, which means that the properties are not same in all directions while metals possess isotropy. So, the mechanical characterization is a complex matter and requires more parameters as compared to metals.
iv. Matrices are generally weak, corroded and also degraded in the environment.

v. While comparing with metals, composite has less service experience and durability.

### 1.9 Conclusion

It may be concluded that composites are a promising material for treatment of water. Wide variety of composite material provide for treatment of various types of impurities present in water.

### 1.10 Future Prospects

In the field of water treatment the green composite material are having a bright future. They are eco friendly and thus are a choice
for environmentalists. Further modifications will provide better results.

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### References


