Structural Features and Biomedical Applications of Biodegradable Polymers

[1]Dr. Santosh Kumar*, [2]Dr. Sumit Sharma,[3]Ms. Shubhangi Satdeve,
[1] Assistant Professor, [2]Associate Professor, [3]Assistant Professor
F.Y. B. Tech Department
G.H.Raisoni College of Engineering and Management, Pune, Maharashtra, India

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Abstract: **Polymers are a unique part of our day to day life. In the last few years, it has been focused more interest in biodegradable materials for use in medicine, agriculture, packaging and other specific areas. A number of bio materials may be incorporated into biodegradable polymer materials, some of them, e.g. fiber and starch extracted from special types of plants. It has shown more trust on biodegradable materials to create positive impact on both economic and environmentally which will overcome the need for synthetic polymer production (thus reducing pollution) at a low price. Now a day biodegradable materials are more demanding in the market and growth is very fast due to its ecofriendly nature. Subsequently, bio materials are burning topics for research and development in interest. These materials can be categorized as biodegradable polyesters [poly hydroxy alkanoates, poly (lactic acid)] and Agro- polymers (protein, starch chitin…)**

Keywords: **Biodegradable Polymers, Biological Materials, Environment Friendly Material, Agro-polymers, Biodegradable Polyesters**.

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1. Introduction:

Biodegradable polymers are a specific type of polymer that breaks down after its intended purpose to result in natural byproducts such as biomass, gases (CO_2, N_2), water and inorganic salts [1] [2]. These polymers particularly consist of ether, amide, and ester functional groups. Their characteristics and breakdown mechanism are determined by their exact structure. Such polymers are frequently prepared by metal catalysts, ring opening polymerization and condensation reactions. Long ago the use of first biomaterial for medicinal purposes was the catgut suture [3]. In 1980s, the idea of synthetic biodegradable polymers was first introduced [4]. An international meeting was called in 1992, where leaders in biodegradable polymers met to discuss a definition, standard, and testing protocol for biodegradable polymers [2]. Also, oversight organizations such as the International Standards Organization (ISO) and American Society for Testing of Materials (ASTM) were created [5]. In the late 2010s, clothing materials and grocery store have been creating a drive for utilization of biodegradable bags. Bio polymers also received more attention from various fields in 2012 when Professor Geoffrey Coates of Cornell University received the Presidential Green Chemistry Challenge Award. As of 2013, around (≈) 10% of the plastic market concentrated on biodegradable polymer derived plastics [6].There is thrust area of many researchers for many years to the development of new and innovative biodegradable polymers. It has been reported by European countries that the average 100 kg of plastic is used per person every year [7]. There are disposal issues for synthetic polymers due to its non-degradable behavior therefore it has attention an internationally for the development of biodegradable polymers. As the development of these materials continues, the industry must discover its innovative applications in various fields. It has been established an incorporated waste organization which has to be planned in order to effectively use, recycle and dispose of biodegradable materials [8]. There are various renewable and non-renewable materials used as feedstock for development new plastic materials. Frequently synthetic polymers are prepared from petroleum-based non-renewable feed stocks [9]. Starch is the main source of renewal feed stocks of polymers. The focus is required to support these polymer materials with natural fibers from plants such as flax, jute, hemp and other cellulose sources[10].The basic concept behind the development of biodegradable polymers because these are easily decomposable and its future depends on cost and consumption. Many governments are introducing initiatives to encourage research and development of biologically based polymers.Maximum Political leaders and governing bodies of Europe and North America support work in this area, however the German government has shown more interest [11]. There is huge scope of biodegradable materials in future for its outlook and development. In the field of biotechnology and its infrastructure Canada's is world class famous, with the provinces of Ontario, Quebec, and Saskatchewan is active and successful in research and development. The long term goal of Canada's in front of the world is to develop technologies that are able to accept a miscellaneous arrangement of raw materials and produce multiple outputs without releasing harmful emissions [12].

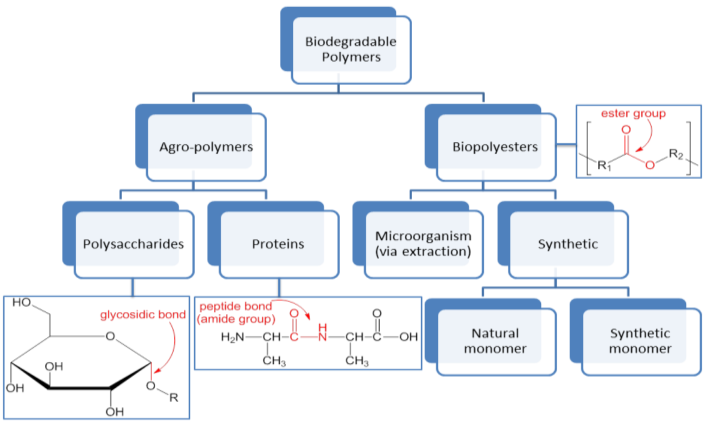
2. Biodegradability and Compostability:

The International Standards Organization (ISO) and the American Society for Testing of Materials (ASTM) define degradable plastics as those which undergo a significant change in chemical structure under definite environmental situations. It has noticed that these varying effect physical and mechanical properties. Biodegradable polymers undergo decomposition like bacteria, fungi, and algae in the presence of microorganisms. Plastics may also be undergoing degradation by action of photodegradable, ox datively degradable, hydrolytically degradable, or those which may be composted. Earlier, there is misunderstanding for right definition of biodegradable polymer. Consequently, ASTM and ISO were decided the common test methods and protocols for degradable plastics [13]. As per the industry and consumers need scientists are focused on three main classes of polymers. Their design is often that of a polymer composite, where a polymer matrix and reinforcing materials being put together with a defined interface.The boundaries between the matrix and reinforcement is called interface. Strength of interracial bonds affects the properties of polymer composites. Reinforcement is structural constituents like fibers, sheets, particles which are embedded in matrix phase and provide high strength, rigidity and enhance the matrix properties.

Compatibility is material biodegradability using compost intermediate. Biodegradation is the degradation of an organic material caused by biological activity (biotic degradation), mainly microorganisms' enzymatic action. The end-products are CO_2, new biomass, and water (in the presence of oxygen, i.e. aerobic conditions) or methane (in the absence of oxygen, i.e., anaerobic conditions), as defined in the European Standard EN 13432-2000. Depending on the type of standard to follow (ASTM or EN), different composting conditions (humidity and temperature cycle) must be realized to determine the compatibility level [14]. Therefore, the comparison of the results obtained from different standards seems to be difficult or impossible. We must also take into account the amount of mineralization as well as the nature of the residues (commonly called ''by-products'') left after biodegradation [15]. The accumulation [16] of contaminants with toxic residues can cause plant growth inhibition. The key issue is to determine the environmental toxicity level for these by-products, which is known as eco-toxicity [17]. Some general rules enable the determination of the biodegradability evolution. For example, an increase in parameters such as the hydrophobicity, the macromolecules molecular weights, and the crystallinity or the size of crystalline domains decreases the biodegradability [18].

3. Structure:

The presence of hydrolyzable and / or oxidisable linkages in the polymer main chain, types of functional groups, substituents present in structure, correct stereo configuration, balance of hydrophobicity and hydrophilicity, crystallinity, molecular weight contributes to the easier biodegradability of polymer. Polymers containing amines or hydroxyl functional groups undergo biodegradation easily as they have a tendency to absorb water, swell and degrade. On the basis of structure and synthesis biodegradable polymers can be classified into i) agro-polymers, or those derived from biomass [1] and ii) bio polyesters, which are derived from microorganisms or synthetically made from either natural or synthetic monomers.



Biodegradable polymers organization based on structure and occurrence

Agra-polymers contain polysaccharides, like starches found in potatoes or wood, and proteins, such as animal based whey or plant derived gelatin. [1] Polysaccharides consist of glycosidic bonds, which take a homicidalof a saccharide and bind it to an alcohol via loss of water. Amino acids are monomeric unit of proteins, which have various functional groups. [19] These amino acids come together again through condensation reactions to form peptide bonds, which consist of amide functional groups. [19] Examples of bio polyesters include polydroxybutyrate and polylactic acid. [1]

4. Practical application of BiodegradablePolymers

Nowadays, thebiodegradablepolymers are used in three important disciplines, e.g. medical, agricultural and goods. Intensive researchin this field has given more attention to the developmentofcommercialproducts. There is high demand of these polymers in medical field due to its high specialization and greater unit values than the other ones

4.1 BiomedicalApplications

The biodegradable polymers are used in various medical applications, e.g. in orthopedicsurgery for controlling the continuing medicine releasewithanOrganism, surgical implantsintheblood vessels andasabsorbableclinicalsutures,aswellasforeyecare.Nowadays, special terminology "biomaterial "used in medical areas that intended to interface with biological systems to evaluate, treat, augment or replace any tissue, organ or function of the body.Itisimportantthattheterm "biocompatibility" was alsoarticulated; it is used in specific application in the presence of host response (the reaction of a living system to the presence of a material).Biocompatibility isthecapabilityofamaterialtolivewithsome host'sreactions inaspecificuse[20, 21].

4.1.1 SurgicalSutures

Tissue damage causes lossofstructuralintegrity: adeep cut in softtissue ora bone fracture, forexample, mayormaynotbecapable ofnaturalcuring. Additionofmaterial ora devicetoholdthewound edges together simplifythetreatment. Thetypicalcaseisthe useofsuturestohold both deepandsurfacewoundstogether. Whenthehealing iscomplete, thesuturesareredundantandmaydisturbhealthy tissues. Itisthen helpfulforthematerial tobechangeable fromthesiteeither physicallyorbydegradation.

The first synthetic sutures was exists in 1960s and it was successfully used in general and tracheobronchialsurgery.Thesuturesusedmostfrequentlyaremultifilament,withgoodhandlingcharacteristics. The sutures prepared fromPGA,PLAand theircopolymers are most often used for commercial purpose. Forlayingcontinuoussutures,however, braidedsutureswithnonsmoothsurfacesarenotuseful.Insuchcasesonlymono-filamentsutureswithsmooth surfaces areuseful, because PLA orPGAprovedtobetoostiffand inflexible. Due to lowbendingmoduli themore flexiblepolydioxanonesand polyglyconatescanbeusedassutures.Moreover, polymersofpolycaprolactoneareal sobio absorbable,elastic in nature, sotheir clinicalprocedureisunder study[22,23]. *Dexon* is thefirstsynthetic polymer established particularlyforproducingsurgical threadmadeofpoly (glycolicacid). This material shows high flexibility, veryeasilyhandledandwithhigh knotsecurity, undergoes hydrolytic in humans, causing minimaltissue reaction.

4.1.2 Bone-FixationDevices

Although metal fixationisan efficient technique forundisturbedbonetreatment, mechanical properties of metal and bone are dissimilar. Steel has shown more elastic property than bone (elasticityconstantofboneis1/10th thatofimplantedsteel),whilethe tensilestrength of the bone is 10 timeslower than steel.For the reason that,removalofmetalimplantscanbringaboutboneweakness andrefractures.Incontrast,biodegradableimplantscanadapttothedynamic processesofbonehealing throughdecreasingamounts ofweight-bearingmaterial.Over afew monthstheintroducedmaterial disappearsandthere isnoneed tooperate onapatient toeliminateit.Inthisfield,PLA,PGA,PHD, andpolydioxanone canpotentiallybeused.Polydioxanoneshavebeensuggested forclinicalusetodefendligamentaugmentation,forsecuringligamentsutures.There are other biodegradable polymers applications also useful in day to day life.Amarrowspacercanhelptosaveautologousbonematerial. Tofilllargebonedefects,polymerfibersareused inordertoavoidmechanicalload[24].

4.1.3 VascularGrafts

Aseveralstudies havebeen commencedtocultivatesuitablevascularprosthesesofsmall diameters.Niluetal.[25]designedsuchsmall-diametervascularprostheseswithmatricesthat wereabsorbedintoagrowing anastomotic meantime. It was shown that agelatin-heparin complex, when sufficiently cross-linked,caninstantaneouslyfunctionasamomentaryantithrombogenicsurfaceandasaperfectsubstructureforananastomotic meantime.

4.1.4 AdhesionPrevention

Post-operation tissueadhesion can infrequently cause severeobstacles.Materials fortissue adhesionpreventionshould beflexibleandtough enoughtoprovideatightcoveroverthedisturbedlenienttissue. Inaddition, theyshould bebiodegradableandreabsorbableaftertheinjuredtissuehasbeenfullyregenerated Matsuda e t*al*.[26,27]developed photocurablemucopolysaccharidesfortissueadhesionprevention materials.Mucopolysaccharidespartially functionalizedwith photoreactivegroups,suchascinnamateorthymine,underwentUVirradiationtoformwater-insolublegelsthroughintermolecularphotodimerizationofthephoto reactivegroups.Thephoto-curedfilmswithlowerdegreesofsubstitutionandofhighswellabilityandflexibility preventedtissueadhesionand showed enhanced biodegradability.

4.1.5 ArtificialSkin

Artificialskinsubstitutesandwound dressingsmade ofbiodegradablepolymericmaterialshavebeen developedtotreat burns.Sofar,most ofthecommerciallyavailableartificialskins havebeencomposedofbiodegradablepolymers, suchas collagenandchitin, whichareenzymatically degradablepolymers [28, 29] .Koide et al. [30],developed anewtypeofbiomaterialintheform ofasponge thatcombinesfibrillar collagen(F-collagen)withgelatin. Thesponge wasphysicallyand metabolicallystabilizedby introduction ofcrosslinks.Although some types of collagen-based artificial skin havebeen developed, some unfavorable qualities ofnativecollagenhavestill beenreported; thesemainlyinvolveintroduction ofrod like shapes andexpression ofcollagenase genes tofibroblasts.New materialshavebeendeveloped tocopewiththese problems.Yasutomi *etal*.[31]developedabiosyntheticwound dressingwithdrugdelivery capability.This medicatedwound dressingconsists ofaspongysheet basedonamixture ofchitosan andderivatizedcollagen,laminatedwithapolyurethanemembrane impregnatedwithantibiotics.

4.1.6 DrugDeliverySystems

Polymeric materials havebeen given anew dimensionforuse asdrug delivery devices bythe introduction ofbiodegradable materials. There various useful applications of these biodegradable material (synthetic andnatural).Theuseofparticularlydevelopeddegradablepolymers inmedicinehasbeen highlighted withthe appearance of some innovations in drug delivery systems. Therestrictionsofclassicmethods fordrugadministration (byinjection ortablet)arewidelyknown. Asadoseisapplied, theplasma levels willgoupbuttheywillfalldrasticallywhen thedrug hasbeen metabolizedandsoonbebelowtherapeuticlevels.The next dose willmake the plasmalevelhigh again and acyclicalpatternmay beestablished.Therefore,inclassical drug administration,maximumofthedrugplasma levelscanbe outside theoptimalrange.Thedrugusuallypermeatesthroughoutthebodyandisnottargeted tothesitewhere itisspecificallyrequired. One ofthepossible solutionstothis problem istouse asystem ofcontrolled drug deliveryinwhich thedrug isreleased ataconstant,preset rate,preferablyclosetothespecificlocation.Oneof the mosteminentapproachesiswhenthedrugiscontained inapolymer membrane(orencapsulated inapolymer matrix),from whichitdiffuses outintothetissue inwhichthemembrane/matrixisimplanted. Insome casesthemechanismofdrug release isaffected byerosion orpolymer dissolution.Degradable materials such aspoly (lacticacid)orpolyorthoesterscanbeused fordrug deliverysystems ofthese type [32, 33] .Some soluble polymers maybeusedascarriers fordrugs. DuncanandKapecek[34]reported theuseofvariouspolymers towhichwereattached,throughlateralgroups, certaindrugsthatcouldbereleasedaftercleavageofthebonds attaching them tothebackbone. Thedrugtargetingwasachievedthrough theuseofbondsthatarecleavedonlyunder certainconditions(e.g.,byliverenzymes), thus allowingdrugreleaseonlyatthespecificsiteofaction. Attempts have beenmadeto obtain plastic biodegradablepolymermaterials.

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