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AN ANALYSIS OF NANOCOMPOSITE METHODS FOR DRUG DELIVERY

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ABSTRACT

New chemical entity formulation and generic development are plagued by low water solubility. More than 40% of pharmaceutical NCEs are water-insoluble. Thus, increasing medication solubility and dissolution is necessary. Nanocomposites improved solubility and dissolving of the nearly insoluble medication. Gelatin, chitosan, polyvinyl pyrollidone, carboxymethyl cellulose, and others produce nanocomposites. Surfactant and wetting qualities determined polymer selection. Solubility tests examine medication solubility enhancement. Fourier transform infrared spectroscopy, differential scanning calorimetry, X-ray diffraction, scanning electron and transmission electron microscopy analyze nanocomposites. Polymer concentration improved medication solubility and dissolution. New technology requires additives with unique qualities and improved performance. Nanocomposites are ideal for medicinal and technological developments.

Keywords: *nanocomposites, polymers, synthesis.*

INTRODUCTION

Formulation development currently struggles with medication solubility. Thus, understanding low water solubility medication dissolution and absorption may help develop more soluble and bioavailable drugs. Negative aqueous solubility limits drug efficacy and most drugs have side effects. Solubility increases efficiency and reduces pleasant pill side effects. Negative water solubility slows medication uptake and bioavailability. 40% of new tablets are water-insoluble. Drug bioavailability sometimes suffers from low gastric fluid aqueous solubility. Poor water solubility drugs need large doses to achieve therapeutic plasma awareness.1-4 Due to their tiny size, high surface-to-volume ratio, and fast tumor penetration, nanoparticles are intriguing drug delivery devices. Despite having the same composition, nanosized fabric has different conductivity, mechanical, and optical properties than bulk cloth.5-7 Nanomaterials' physical, chemical, and biological properties span from character atoms and molecules to bulk. By creating nanoparticles, it's possible to change materials' melting temperature, magnetic properties, charge capacity, and even color without affecting their chemical compositions.8 Petrochemical-based synthetic polymers deteriorate slowly and are toxic. Biodegradable polymer overcomes this drawback. Microorganisms and enzymes degraded polymers. Herbal or synthetic biodegradable polymers exist. Chitosan, collagen, silk, and protein are biopolymers. PLA, polyglycolic acid, poly-l-lactic acid, and poly-e-caprolactone are synthetic biopolymers. Drug transportation using artificial degradable polymer has increased in recent years. Due to their biodegradability, sustainability, and availability, biopolymers, polysaccharides, proteins, lipids, and their mixtures have become packaging materials. Biopolymer films and coatings provide mechanical and oxygen barrier properties. Drug delivery, gene therapy, tissue engineering, and plastics employ biodegradable polymers.1 Nanocomposite compounds are grouped by their matrix substances into three categories:

1. Ceramic Matrix Nanocomposites (CMNC);
2. Metal Matrix Nanocomposites (MMNC) and
3. Polymer Matrix Nanocomposites (PMNC).[9]

HISTORY OF NANOCOMPOSTES

Nanocomposites have been investigated for approximately 50 years, but few studies discuss how organoclay is processed into the preferred plastic. Polyamide nanocomposites were originally mentioned in 1976, and nanocomposites in 1950. Nanocomposites were not extensively explored in academic and industrial facilities until Toyota researchers began an in-depth study of polymer/layered silicate clay mineral composites. Acquarulo & O'Neil (2002) found that Toyota's Central Research and Development Laboratories began experimenting on polymer-layered silicate-clay mineral composites in the early 1980s, when the technique was first researched. Montmorillonite, often known as nanoclay and bentonite, is the clay mineral most used for nanocomposites. Bentonite is widely available and inexpensive, making it the most widely used clay in nanocomposite applications, according to Briell (2004). “Toyota first used clay/nylon-6 nanocomposites for Toyota automobile to produce timing belt covers” in 1990, according to Azonano (2009). He noted:

- Mitsubishi´s GDI cover clay/nylon-6 nanocomposites engines; and
- General Motors clay/polyolefin nanocomposites step assistant GMC Safari and Chevrolet Astro vans.

Since Toyota introduced polymer/clay car parts and capacity packages went beyond automotive, nanocomposites were employed commercially. Polymer clay nanocomposites' increased barrier properties make drink packaging promising. This topic is clearly industrial and technological. New nanocomposites employ nanometer-scale fillers due to breakthroughs in representing, producing, and controlling them.[10]

What are Nanomaterials?

Nanomaterials and nanoparticles have at least one nanoscale dimension. These nanoparticles come from volcanic ash, forest smoke, etc. Welding and diesel engines produce them. These particles are diverse and exceedingly fine. Floor area may affect nanomaterial behavior more than particle composition. Relative-floor proximity boosts reactivity, power, and electrical qualities. Healthcare, electronics, cosmetics, fabrics, recordkeeping, and environmental safety use nano-scale trash, tubes, rods, or fibers. Nanomaterials aren't always well-characterized. The following nanomaterial properties are important:

Nanomaterials may be metals, ceramics, polymers, or composites with many homes and packaging. These include small digital devices, biomedical batteries, packing films, amazing absorbents, armor additives, and motor parts. Nanotechnology may target particular organs or cells, including cancer cells, to improve drug efficacy. Nanomaterials can strengthen and lighten cement, cloth, and other materials. They can neutralize poisons and clean up the environment due to their size. Engineered nanoparticles have specified shape, length, floor residences, and chemistry. Laser ablation, HiPCO (excessive-pressure carbon monoxide), arc discharge, and CVD may create these nanoparticles experimentally. These compounds have precise optical, magnetic, electrical, and other properties and have greatly impacted electronics, medicine, and other fields. Engineered nanomaterials include nanocrystals (quantum dots surrounded by semiconductor materials), nano-scale silver, dendrimers (repetitively branching molecules), and fullerenes (carbon molecules in the shape of a hollow spherical, ellipsoid, or tube). Engineered nanomaterials have wonderful advantages, but their potential effects on human health and the environment aren't generally known. Nanoparticles may enter the body by inhalation, ingestion, and skin. Asbestos-like carbon nanoparticles cause lung irritation.[8,11,12]

POLYMERS

Mechanical chemical properties, hydrophobic/hydrophilic stability, chemical stability, biocompability, and chemical functions determine which polymers make good composites. Environmental polymers include PDMS, PANI, PVB, PVP, PMMA, PVDF, PE, CMC, alginate, and chitosan. Filtration, water remediation, disinfection, and others may use these polymers as polymeric matrices. Environmental cleanup due to their chemical and physical properties and synergistic interaction between polymers and the other composite component. Recent nanocomposites preparation breakthroughs using polymer diffusion are thoroughly explored in this phase.

1. Poly(dimethylsiloxane) (PDMS)

Remediation programs employ sponge-shaped PDMS, an inert, risk-free, nonflammable, and very flexible polymer. PDMS sponges may be duplicated from sugar templates without expensive synthesis methods. Due to their hydrophobic/oleophilic properties and molecular structure, they may selectively absorb oil. PDMS sponge can absorb oils and natural solvents and remove them, and it may be reused. The shape's sugar carbohydrate debris may also modify the sponge's absorption capability. Thus, PDMS sponge comfort homes are necessary to remove toxic compounds from oil spills and organic contamination from water.

2. Polyaniline (PANI)

PANI has unique chemical and physical properties in different forms. Leucoemeraldine (LEB), emeraldine (EB), and pernigraniline (PB) are PANI systems that may share synthesis methods. PANI is used in organic electrodes, sensors, and actuators because of its physicochemical properties. Conductive polymer PANI is used to remove chromium(VI) (Cr(VI)) because to its wide surface area, cheap cost, and easy manufacture. However, Cr(VI)-removing investigations are difficult, and Cr(VI)-PANI reactions are crucial to environmental remediation. Thus, PANI-magnetite nanocomposites were created to study PANI-Cr(VI) reactions. In another study, PANI and TiO2 removed Cr(VI) from contaminated water quickly and efficiently.

3. Poly(hydroxybutyrate) (PHB)

PHB is a linear polyester p-hydroxyacid. This biodegradable plastic for marine, agricultural, and scientific uses may be manufactured from natural sources. PHB degrades in soil and other settings in weeks. PHB is biodegradable, unlike polypropylene (PP), however its high cost makes it unpopular. Thus, current research has examined bacterial pressure development, green fermentation/recovery, and renewable resources to produce lower-value PHB. To remove methylene blue from the environment, it was mixed with metal oxides, including TiO2.

4. Poly(vinyl pyrrolidone) (PVP)

PVP, a water-soluble polymer, is widely used in colloidal suspensions due to its mechanical balance, chemical inertness, optical transparency, and binding and adhesion properties. PVP bonds, disperses pigments, and stabilizes suspensions. PVP nanocomposites have chemical and mechanical balance because to their saturated carbon chain. Polymeric pyrrolidone residue retains polar molecular and ionic species owing to its polarity. This function removes bromate from water.

5. Poly(methyl methacrylate) (PMMA)

Due to its dimensional balance, optical readability, and compatibility with ceramics, PMMA is used to train PNCs for environmental cleanup. Magnetic nanoparticles may improve PMMA's balance and dispersibility for environmental cleanup. Nontoxicity, simple production, and occasional pricing make this fabric suitable. Due to component qualities, PMMA-lined nZVI debris is environmentally friendly. PMMA is insoluble but may swell in organic solvents like TCE. PMMA's glass-transition temperature (Tg) is lower than other polymers, and lowering Tg makes composite morphology analysis easier.

6. Poly(vinylidene fluoride) (PVDF)

Compared to commercial polymers, PVDF's thermal balance, mechanical strength, chemical resistance, and hydrophobicity make it a desirable membrane material. Ultrafiltration and microfiltration use PVDF membranes. Membrane contactors and membrane distillation also use PVDF. Green PVDF membrane manufacture for the above applications and wastewater cleanup has advanced greatly. PVDF is more hydrophobic than polypropylene (PP) and polytetrafluoroethylene (PTFE), but not as much. PVDF's thermal balance makes it ideal for industrial membrane textile applications. Biomedical and separation applications use PVDF, a natural polymer. PVDF is a semicrystalline polymer with 59.4wt% fluorine and 3wt% hydrogen. Polymer crystallinity and membrane shape determine mechanical homes. Due to fluorine atoms' high electronegativity and strong CdF bonding, PVDF is more thermally stable than other hydrocarbon polymers. PVDF cannot withstand high reaction temperatures.[8]

7. Polyethylene (PE)

8. PE, an amorphous crystalline polymer made from ethylene fuel, is utilized in environmental remediation encapsulation. PE encapsulation stabilizes and remediates. PE's flash-ignition temperatures are 409°C and 430°C, and the National Fire Protection Association rates its flammability as 1 (moderate). However, UV light may destroy PE's plasticity. In light of those properties of PE, studies have shown that the PE/TiO2 polymer nanocomposite, synthesized by immobilizing TiO2 powder on a foamed PE sheet, can decompose a variety of natural substances, such as natural dye and methylene blue, and is useful for wastewater treatment.

9. Alginate

10. Few algae or bacteria make alginate, a polysaccharide. Industrial alginate comes from brown algae (Phaeophyceae). The linear binary copolymer contains coupled 1,4-β-D-mannuronic acid (M) and 1,4-β-L-guluronic acid (G). Biomedicine uses alginate hydrogel for wound healing, tissue engineering, and biosensor packaging. Alginate's open lattice structure provides significant porosity for encapsulation. Alginate's molecular weight and M and G corporation sequence affect its physical characteristics. Nontoxicity,

biocompatibility, chelating capability, and hydrophilicity make it ideal for environmental cleanup. Calcium-alginate is safe, biodegradable, and somewhat water-soluble, making it the best composite for environmental projects. Ca-alginate's porous nature allows solutes to permeate and contact the entrapped nano-scale Fe0, creating a promising polymer composite for environmental cleanup.

PROPERTIES OF NANOCOMPOSITES

- Nano-composites are trending. Nanostructures are being controlled artificially. Nano-composite substances' qualities depend on their shape, interfacial features, and parent properties. Nanomaterials have distinct physical, chemical, and organic properties. Nanoparticles may modify materials' melting temperature, magnetic properties, rate potential, and color without affecting their chemical compositions. Polymeric materials benefit from nano-debris and nano-layers' high surface-to-volume and factor ratios. These structures combine component quality to improve mechanical and superconducting properties for advanced projects. Nano-composites' properties rely on their morphology, interfacial features, and parent properties. Some nanocomposite materials are 1,000 times tougher than others. Nanocomposite natural/inorganic materials are a hot research topic. Zeolites, clays, metal oxides, metallic phosphates, chalcogenides, one-dimensional and zero-dimensional materials, and (Mo3Se3-)n chains and clusters may be inorganic additives. Thus, nanocomposites provide novel packaging for mechanically reinforced lightweight additives, non-linear optics, battery cathodes, nano-wires, sensors, and other systems. Many inorganic layered materials exist. Foreign species have well-defined, organized intralamellar areas. They may form hybrid nano-composites as polymer matrices. Lamellar nanocomposites are extreme composites with maximum interface interactions between phases. Nanocomposites with diverse residences may be made by tailoring polymer-host interactions. Intercalated and exfoliated lamellar nanocomposites are amazing. The former alternates polymer chains with inorganic layers in a constant compositional ratio and has a well specified number of polymer layers within the intralamellar space. Exfoliated nano-composites have >100 Å layers with varying polymer chain counts. Digital and fee transport properties benefit intercalated nanocomposites. Exfoliated nano-composites have superior mechanical properties. The electronics industry uses flexible, durable, high-dielectric-constant materials. Finding single-aspect materials for these houses is difficult. The most often used ceramic materials with high dielectric constants are brittle and treated at high temperatures, whereas polymer materials with low dielectric constants are easy to process. Composite materials with micron-scale ferroelectric ceramic debris as filler in liquid crystal polymer, fluoropolymer, or thermoplastic polymer matrices are difficult to produce into thin uniform films required in many microelectronics applications. Nanocomposite materials with many nanometer-scale substances are needed. Optimized production technology and regulated nano-sized second segment dispersion improve thermal balancing and mechanical properties such adhesion resistance, flexural electricity, lifespan, and hardness, resulting in advanced nano-dispersion. Drug distribution, corrosion prevention, electronic/car parts, industrial systems, and others may benefit from low-cost materials with customized physical and digital properties. Nanocomposites are materials with nanoparticles in a matrix. Nanoparticles increase home durability, mechanical energy, and electrical or thermal conductivity. Nanoparticles are most effective at 0.5–5% weight. Nanocomposites are clay, polymer, carbon, or a mixture of these with nanoparticle building units. Their high floor-to-extent ratio drastically alters their qualities compared to bulk-sized analogues. It alters nanoparticle bonding with the majority fabric. The composite may often be enhanced relative to the problem portions. Nanocomposite materials are 1,000 times harder than bulk components.

Nanocomposites greatly improve:

- Mechanical residences which include energy, modulus and dimensional balance.
- Electrical conductivity.
- Decreased gas, water and hydrocarbon permeability.
- Flame retardancy.
- Thermal balance.
- Chemical resistance.[10]

METHODS TO GENERATE NANOCOMPOSITES

Methods which can be used for the coaching of nanoparticles can be used to prepare nanocomposite with some change.

1. Emulsion/solvent evaporation

It relies on emulsion and solvent evaporation. Nanoprecipitates develop from solvent evaporation and vigorous stirring. Hydrophobic tablets fit. Drug and polymer are dissolved in common natural solvent to create oil phase. Polymer is water-soluble. To form an oil-in-water emulsion, the oil portion is continuously stirred or sonicated. To form drug-loaded nanocomposite particles, solvent is allowed to evaporate. Oil-in-oil emulsion contains two oil phases. Drug and polymer solubility determines oil and aqueous phases in this approach. Paclitaxel-loaded PLGA/MMT nanocomposite in DCM. 5 mg paclitaxel and 110 mg PLGA were dissolved in DCM to make an oil section solution. Aqueous solution contains 2% PVA and 0, 0.046%, and 0.092% MMT. Sonication for 120 s emulsifies the oil section in the aqueous. To harden debris, the emulsion evaporated overnight at room temperature.

2. Emulsification solvent diffusion

Emulsification and solvent diffusion to outer portion generate nanocomposite particle precipitate. Solubility in outer phase allows solvent diffusion. Nanoprecipitates develop through solvent diffusion and high-pressure stirring. Solubility and swelling determine which solvents dissolve polymers. To make nanocomposite particle, inner natural oil segment is emulsified in outer aqueous section with constant stirring or homogenization. Emulsification solvent diffusion organized PLA/MMT nanobiocomposite emulsion. PLA solution and MMT dispersion were each produced in ethyl acetate solvent. As an oil section, PLA solution, clay dispersion, and lauryl alcohol were mixed. Surfactants and PVA in distilled water make the aqueous section. Homogenization and magnetic stirring distribute oil in aqueous phase.

3. Ultrasonication

Ultrasonic waves nanosize material here. This method ultrasonicates polymers in ethanol to create nanobiocomposite. Last solvent eliminated. Irradiation frequency, duration, and power influence nanobiocomposite length and morphology. Ultrasonication formed PEA ZnO nanobiocomposite. They modified ZnO nanoparticles using -methacryloxypropyltri-methoxysilane and

PEA as a matrix. Ice-water ultrasonic tubs produce PEA dispersion in ethanol. After adding varied proportions of modified ZnO nanoparticle in PEA suspension, aggregate was ultrasonicated for 4 h. After solvent removal, nanobiocomposite dried.

CHARACTERIZATION OF NANOCOMPOSITES

Morphological characterization

Following techniques are used for morphological characterization.

1. **XRD (X-ray Diffraction) techniques**

XRD interpretation uses X-ray (monochromatic) and crystalline pattern positive interference. Bragg's law explains constructive interference. XRD determines nanofiller, drug, and polymer form, crystalline, and amorphousness. It determines nanofiller-polymer segment separation. Exfoliated or intercalated layered silicate with polymer is diagnosed.

2. **FTIR (Fourier Transform Infrared Spectroscopy)**

Each practical organization has a consistent resonance frequency during infrared irradiation to find this beneficial group. It measures nanobiocomposite helpful organization changes. Polymers changed chemically during composite production, and drug may be identified. It also recognizes unknown metal in pattern, great, consistency, and amount of element in combination. It determines intermediate and received particle chemistry.

Thermal evaluation

1. **TGA (Thermal Gravimetric Analysis)**

It measures sample weight variation with temperature and time. Compare single polymer and composite weight reduction. It signifies physical processes like melting and chemical changes like burning that reduce weight. The weight of the sample is displayed against time or temperature to demonstrate thermal alterations in the material, including solvent loss, hydration in inorganic compounds, and breakdown.

2. **DSC (Differential Scanning Calorimetry)**

This approach determines crystallization, exothermic, and endothermic response. In endothermic reactions, stable pattern melts to a liquid, requiring more heat to raise its temperature at the same rate as the reference because pattern absorbs heat to become liquid. Endothermic process during crystallization reverses. Melting factor indicates natural polymer and nanobiocomposite thermal stability.

3. **Magnetization**

Magnetic nanobiocomposite characterization uses it. It shows how nanobiocomposite's magnetic power changed after being made. It tests nanobiocomposite reaction to external magnetic field. It also advises on magnetic asset temperature. VSM and SQUID are utilized. VSM uses Faraday's law of induction to detect electric current from changing magnetic field. Magnetization begins with pattern in consistent magnetic topic. Magnetic dipole second vibrates sample to produce magnetic discipline. Magnetic field interchange changes electric field. It implies material magnetism.

APPLICATION IN DRUG DELIVERY

1. **Control release**

Pulsatile medication delivery may use hydrogel-magnetic debris nanocomposite. NIPAAm magnetic nanocomposite remote drug launch. NIPAAm is a temperature-sensitive hydrogel, and iron oxide heats remotely. Alternating high-frequency magnetic subject heats nanocomposite, forcing hydrogel swelling. Temperature increases decrease medication launch. Sodium alginate/hydroxyapatite nanobiocomposite controls diclofenac medication launch. Oral pharmaceuticals will employ nanocomposite beads. Nanocomposite released diclofenac eight hours longer than sodium alginate hydrogel beads. Glycolic acid-g-chitosan-gold-nanoflower nanocomposite medication release control. Nanohybrid scaffolds were stable to medium pH. Biocompatibility characterizes nanohybrid scaffolds. In pH 7.4 buffer, this nanocomposite controlled drug release. Thus, the glycolic acid grafted chitosan-based drug transport machine may use gold nanoflowers.

2. Sustained release

A sustained release nanobiocomposite including hyaluronan, methylcellulose hydrogel, and PLGA nanoparticle proved safe and biocompatible for spinal cord injury training. This training was well-tolerated in intrathecal wounded rats for 28 days, with no increase in irritation, scarring, cavity extent, or locomotor ability.

3. Anticancer

PLGA-MMT nanobiocomposite for oral paclitaxel administration. Paclitaxel's limited GIT absorption and first-bypass action prevent oral administration. CaCo-2 and HT-29 cells absorbed more GIT and boom cells from PLGA-MMT nanocomposite. The drug release test showed an early burst followed by a steady, persistent release, unaffected by MMT. The nanobiocomposite of hydroxyapatite-chitosan with celecoxib medication delivers colon cancer drugs effectively and safely. Nanocomposite debris overcome aspect effect and demonstrated greater anticancer activity than loose celecoxib.

CONCLUSION

Poorly soluble medicines need optimum solubility for oral bioavailability. Oral absorption of weakly water-soluble drugs depends on drug dissolution, which might affect in vivo absorption. Many medications have solubility issues that reduce bioavailability. Over 40% of pharmaceutical New Chemical Entities are water-insoluble. Drug solubility improvement is still difficult. Many devices have been developed to improve medication solubility and dissolution. Nanocomposites improve medication solubility. Nanocomposites are made using many processes. Both laboratory and scale-up procedures have worked.

REFERENCES

1. *Gattani S. G., Patwekar S. L. Enhancement solubility and dissolution Rate of Ibuprofen by Nanobiocomposites using Microwave Induced Diffusion (MIND) Method. World Journal Of Pharmacy and Pharmaceutical Sciences, 2017; 6(11):716- 740.*
2. *Shinde, Patil SS, Mevekari FI, Satpute AS. An approach for solubility enhancement: solid dispersion. International Journal of Advances in Pharmaceutical Sciences, 2010; 1:299-308.*
3. *Jain P, Goel A, Sharma S, Parmar M. Solubility Enhancement Techniques with Special emphasis on Hydro trophy. International Journal of Parma Professional's research, 2010; 1:34-45.*
4. *Chhaprel P, Talesara A, Jain AK. Solubility enhancement of poorly water soluble drug using spray drying technique. International Journal of Pharmaceutical studies and research, 2012.*
5. *Patwekar S. L., Jamkhande P., Gattani S. G., Payghan S. A. Nanobiocomposite: A New Approach to Drug Delivery System. Asian Journal of Pharmaceutics, 2016; 10(4):646-656.*
6. *Desai N. Challenges in development of nanoparticle based therapeutics. AAPS J 2012; 14:282-95.*
7. *Lau A.K., Hussain F, Lafdi K. Nanomaterials formulation and toxicity impact. In:Nano- and Biocomposites. New York: CRC Press; 2010: 291-359.*
8. *Baksi S., Biswas S. Nanocomposites – An Overview. The Scitech Journal, 2014; 1(5):22-30.*
9. *Camargo P. H., Satyanarayana K. G., Wypych F., Nanocomposites: Synthesis, Structure, Properties and New Application Opportunities. Materials Research, 2009; 12(1):1- 39.*
10. *Okpala C. C., Nanocomposites – An Overview. IJERD, 2013; 8(11):17-23.*
11. *Juh Tzeng Lue, Physical Properties of*

Nanomaterials, Encyclopedia of Nanoscience and Nanotechnology, 2007, Volume X: 1–46.

12. *SChen SY, Chang LW, Peng CW, Miao HY, and Lue JT, J. Nanosci. Nanotechnol. 2005, 5:1987.*

13. *Ucankus G., Ercan M., Uzunoglo D., Culha M. Methods for preparation of nanocomposites in environmental remedation. New Polymer Nanocomposites for Environmental Remediation, 2018: 1-28.*

14. *Gattani S. G., Patwekar S. L. Solubility and Dissolution Enhancemnet of Poorly water soluble Ketoprofen by Microwave – assisted Bionanocomposites : In vitro and In vivo study. Asian Journal of Pharmaceutics, 2016; 10(4):601-611.*

15. *Nayak A, Panigrahi PP. Solubility Enhancement of Etoricoxib by Co solvency Approach. International Scholarly Research Network ISRN Physical Chemistry, 2012; IJPSR/Vol.III/ Issue II/April-June, 2012/01-05.*

16. *Kushare SS, Gattani SG. Microwave-generated bionanocomposites for solubility and dissolution enhancement of poorly water-soluble drug glipizide: in-vitro and in-vivo studies. Journal of Pharmacy and pharmacology, 2012.*

17. *Okada A, Kawasumi M, Usuki A, Kojima Y, Kurauchi T, Kamigaito 212. O. In: Schaefer DW, Mark JE, editors. Polymer- based molecular composites. Proceedings of the MRS Symposium; 1990; Pittsburgh. USA: [s.n]; 1990. p. 18-45.*

18. *Gojny FH, Wichmann MHG, Kopke U, Fiedler B, Schulte K. 233. Carbon nanotube-reinforced epoxy-composites: enhanced stiffness and fracture toughness at low nanotube content. Composites Science and Technology. 2004; 64(15):2363-2371.*

19. *Giannelis EP. Polymer-layered silicate nanocomposites: synthesis, 239. properties and applications. Applied Organometalic Chemistry. 1998; 12(10-11):675-680.*

20. *Ray SS, Yamada K, Okamoto M, Ogami A, Ueda K. 263. New polylactide / layered silicate nanocomposites. 3. High- performance biodegradable materials. Chemistry of Materials. 2003; 15(7):1456-1465.*

21. *Aleksandrova GP, Krasnikova IM, Grishchenko LA, Medvedeva SA, Chetverikova TD. Synthesis and antianemic activity of nanosized biocomposite ferroarabinogalactan. Russian J Bioorg Chem 2011; 37:829-33.*

22. *Venkatesan P, Puvvada N, Dash R, Kumar BN, Sarkar D, Azab B, et al. The potential of celecoxib-loaded hydroxyapatite-chitosan nanocomposite for the treatment of colon cancer. Biomaterials 2011; 32:3794-806.*

23. *Chamundeeswari M, Senthil V, Kanagavel M, Chandramohan SM, Sastry TP. Preparation and characterization of nano biocomposites containing iron nanoparticles prepared from blood and coated with chitosan and gelatin. Mater Res Bull 2011; 46:901 4.*

24. *Rupesh Khare, Suryasarathi Bose, 2005. Carbon Nanotube Based Composites- A Review, Journal of Minerals & Materials Characterization & Engineering, Vol. 4, No.1, pp 31-46.*

25. *Das R. K., Babu P. J., Gogoi, N., Sharma, P., Bora, Microwave- Mediated Rapid Synthesis of Gold Nanoparticles Using Calotropisprocera Latex and Study of Optical Properties. ISRN Nanomaterials doi; [2012], 10.5402//650759.*

26. *M.M. Rahman, et al., Hydrazine sensor based on silver nanoparticle-decorated polyaniline tungstophosphate nanocomposite for use in environmental remediation, Microchim. Acta 2016; 183(5):1787–1796.*

27. *J. Zhu, et al., Magnetic nanocomposites for environmental remediation, Adv. Powder Technol. 2013; 24(2):459–467.*

28. *Bonde MN, Sohani AC, Daud AS, Sapkal NP: Microwave: An emerging trend in pharmaceutical processes and formulations; International Journal Of Pharmacy & Technology 2011; 3(4):3499-3520.*

29. *Dobrzanski LA, Bilewicz M, Viana J. Polymer nanocomposites reinforced with montmorillonite. Archives of Materials Science and Engineering. 2012; 53(1):5–28.*

30. *Khankrua R, Pivsa S, Hiroyuki H, Suttiruengwong S.Thermal and mechanical properties of biodegradable polyester/silica nanocomposites. 10th Eco-Energy and Materials Science and Engineering Symposium, Energy Procedia. 2012; 34:705–13.*