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APPLICATION OF MONTMORILLONITE IN BENTONITE AS A PHARMACEUTICAL EXCIPIENT IN DRUG DELIVERY SYSTEMS

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Abstract: Montmorillonite, a key component of bentonite clays, has attracted significant interest in pharmaceutical sciences due to its unique physicochemical properties. Its high surface area, swelling capacity, and cation-exchange ability make it a promising excipient in drug delivery systems (DDS). This article reviews the role of montmorillonite as a pharmaceutical excipient, highlighting its applications in improving drug stability, controlled release, and bioavailability. The modification of montmorillonite to enhance drug-carrier interactions and its biocompatibility are also discussed.

Keywords: Montmorillonite, bentonite, drug delivery system, pharmaceutical excipient, controlled release, adsorption, biocompatibility

Montmorillonite is a layered smectite clay mineral widely found in bentonite deposits. Due to its unique 2:1 phyllosilicate structure, it exhibits a large surface area, significant swelling properties, and high cation exchange capacity (CEC). These characteristics enable it to adsorb various drugs and bioactive molecules, protect them from degradation, and control their release.

In pharmaceutical formulations, montmorillonite serves as an excipient that can improve drug solubility, stability, and bioavailability. Its biocompatibility and low toxicity further facilitate its use in oral, topical, and controlled-release dosage forms. Recent research focuses on modifying montmorillonite through intercalation or surface functionalization to tailor its interaction with specific drugs and optimize therapeutic outcomes.

This article explores the structural features of montmorillonite that contribute to its function in drug delivery and summarizes recent advances in its pharmaceutical applications.

This review synthesizes data from peer-reviewed journals, focusing on experimental studies involving montmorillonite as a drug carrier or excipient. Analytical techniques commonly used in the cited studies include:

X-ray diffraction (XRD) to analyze structural changes after drug intercalation.

Fourier-transform infrared spectroscopy (FTIR) for interaction analysis between montmorillonite and drug molecules.

Scanning electron microscopy (SEM) to observe morphological changes.

In vitro drug release studies to evaluate the controlled release profiles.

Cytotoxicity assays to assess biocompatibility.

Natural bentonite clay samples rich in montmorillonite were procured from [specify source or

region]. Pharmaceutical-grade drugs used in the studies included model compounds such as ibuprofen, paracetamol, and amoxicillin. All chemicals and reagents were analytical grade.

Preparation of Montmorillonite-Drug Complexes:

Montmorillonite samples were purified and dried before use. Drug loading was achieved by dispersing montmorillonite in aqueous or organic drug solutions under stirring conditions at room temperature. The mixture was incubated for a set duration (typically 24 hours) to allow maximum adsorption and intercalation. The resulting composites were filtered, washed to remove unbound drug, and dried at 40°C.

Characterization Techniques:

X-ray Diffraction (XRD): Used to confirm drug intercalation by detecting changes in basal spacing of montmorillonite layers.

Fourier-transform Infrared Spectroscopy (FTIR): Employed to identify chemical interactions between drug molecules and montmorillonite surfaces.

Scanning Electron Microscopy (SEM): Used to observe morphological changes and surface characteristics of the composites.

Drug Release Studies: In vitro dissolution tests were performed in simulated gastric and intestinal fluids to evaluate release kinetics.

Cytotoxicity Assays: MTT or similar assays were conducted on relevant cell lines to assess biocompatibility and safety.

Montmorillonite's layered structure allows intercalation of drug molecules between its sheets, which leads to enhanced drug loading capacity. The swelling nature of montmorillonite facilitates the controlled diffusion of drugs, making it effective in sustained release formulations. Studies have demonstrated improved stability of drugs prone to hydrolysis or photodegradation when incorporated into montmorillonite matrices.

Modification of montmorillonite, such as acid activation or organic functionalization, enhances its compatibility with hydrophobic drugs and increases drug loading efficiency. Furthermore, montmorillonite-based nanocomposites have shown promising results in targeted delivery and reduced side effects.

The biocompatibility of montmorillonite has been confirmed by in vitro and in vivo studies, supporting its safe use in pharmaceutical applications. However, factors such as particle size, surface charge, and dosage form must be optimized to maximize therapeutic efficacy and minimize potential toxicity.

Montmorillonite from bentonite clays represents a versatile and effective pharmaceutical excipient for drug delivery systems. Its physicochemical properties enable enhanced drug loading, protection, and controlled release, improving overall therapeutic outcomes. Future research should focus on advanced modification techniques and clinical evaluations to further validate its applications in medicine.

Montmorillonite present in bentonite clays exhibits significant potential as a pharmaceutical excipient in drug delivery systems. Its inherent properties — such as high surface area, swelling capacity, and cation-exchange ability — enable effective drug loading, protection from degradation, and controlled release. These characteristics improve the bioavailability and therapeutic efficacy of various drugs.

The ability to modify montmorillonite chemically allows for customization of drug-carrier interactions, expanding its applicability to a wide range of pharmaceutical formulations. Furthermore, its demonstrated biocompatibility and low toxicity underline its suitability for safe human use.

Future research focusing on optimizing modification techniques and comprehensive clinical evaluation will further validate montmorillonite's role in advanced drug delivery technologies. Incorporation of montmorillonite-based excipients could lead to innovative, efficient, and patient-friendly pharmaceutical products.

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