JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

A Review Article on Nanoparticle Based Topical Gel

Saket Tiwari, Dr. Rakhee Kapadia Jain (Professor SAGE University)

Abstract

A rapidly expanding class of materials notable for their intricate structures has garnered significant interest due to its diverse applications. Comprehensive characterization—covering elemental composition, crystal dimensions, morphology, and other physical properties—has been pursued using a wide array of techniques. While each method offers distinct advantages, selecting the optimal one can be challenging; often, a multimodal characterization strategy is essential. Moreover, given the paramount importance of nanoparticles in both foundational research and practical applications, it is crucial for interdisciplinary researchers to address the challenges of achieving reproducible and reliable nanoparticle synthesis and characterization.

Introduction

Definition and Size Classification Nanoparticles are particles typically ranging from 1 to 100 nm in at least one dimension. Sub-1 nm aggregates of metal atoms are often referred to as atom clusters. These particles are distinguished from [1][2][3]

- **Fine particles**: 100–2,500 nm
- **Coarse particles**: 2,500–10,000 nm
- **Unique Properties**

Compared to larger counterparts of the same chemical composition, nanoparticles frequently exhibit vastly different characteristics. Their high surface-to-volume ratio often causes surface effects to dominate, sometimes even overriding bulk properties. Quantum effects, such as quantum confinement, also become significant at this scale, altering optical, electronic, and magnetic behaviours [4][5][6]

Description of Nanoparticles

Nanoparticles—commonly referred to as ultrafine particles—are defined as materials with dimensions measured in nanometres (nm), typically ranging from 1 to 100 nm. They can occur **naturally**—such as via volcanic ash or biological processes—or be **synthetically manufactured** through chemical, physical, or biological methods. Engineered nanoparticles exhibit unique properties due to their tiny size and large surface-area-to-volume ratio, enabling applications across diverse fields such as medicine (e.g., drug delivery, imaging), engineering, catalysis, and environmental remediation. [7][8][9]

Standard Definitions

In 2008, ISO (via TS-80004-2) defined a **nanoparticle** as a Nano-object whose three external dimensions lie within the nanoscale (approximately 1–100 nm) and whose longest and shortest axes do not differ significantly (4)

In 2011, the European Commission formally adopted a definition in Commission Recommendation 2011/696/EU: any natural, incidental, or manufactured particle— either unbound, aggregated, or agglomerated—where **50 % or more** of the particles have **at least one** external dimension between 1–100 nm

This definition was updated in 2022 (Recommendation 2022/C 229/01), but the core criteria remain

consistent [10] [11] [12]

Dimensional Classification of Nano-Objects
ISO's framework categorizes Nano-objects by dimensionality

- **1D Nano-objects**: nanorods, nanotubes, or nanofibers (one dimension outside the nanoscale).
- **2D Nano-objects**: nanoplates or nanosheets/discs (two dimensions ≪ 100 nm, one dimension ≫ 100 nm).

Even if **none** of its dimensions fall strictly within 1–100 nm, such an object can still be considered a nanoparticle if it meets other ISO criteria. [5][6][8]

Material and Functional Classifications
Nanoparticles are categorized both by **composition** and **function**:

- **By composition**: ceramics, semiconductors, carbon-based (e.g., fullerenes, graphene), and polymers.
- **By nature**:
  - **Hard nanoparticles** (e.g., titanium dioxide, silicon dioxide, fullerenes).
  - **Soft nanoparticles** (e.g., liposomes, vesicles, nanodroplets).

The chosen classification often depends on their intended application— therapeutic, diagnostic, or basic research—or their synthesis method. [4]

- **Nanoparticle based technology**
- Nanoparticle technology is designed to make many processes **better, more practical, and faster**. It achieves this by using **less material**, much of which is already highly reactive, unlike the materials typically used in industries (like industrial catalysts). One exciting application is using **tiny iron particles (nanoscale zero-valent iron)** to clean up harmful chemicals like PCBs from the environment, even reaching deep underground to reduce pollution in water sources. Nanoparticles are also being used to create **stronger coatings, new materials, and better additives** by carefully arranging matter at an incredibly small scale. Plus, their unique **quantum properties** are leading to breakthroughs in areas like medical imaging (quantum dots), tiny electronics (nanowires), and advanced magnetic technologies. [5][7]
- **Nanoparticle application in materials**
- The exceptional qualities of nanoparticles are a direct result of their **particle size**. Recognizing this, researchers have actively sought to embed nanoparticles into composite materials, aiming to unlock and utilize these beneficial traits. A clear illustration of this successful integration is the **modern rubber tire**, a nanocomposite that benefits from nanoparticles' special features. These materials are commonly created by blending rubber with organic fillers like **carbon or silica nanoparticles**.

Nanoparticles Analysis

Nanotechnology is the study and application of materials at an incredibly small scale. While not confined to a single industry, it generally focuses on creating materials or technologies within a 100-nanometer (nm) structure. Instruments like the SZ-100 Nanoparticle Analyzer, using **Dynamic Light Scattering technology**, help characterize these tiny materials.

This field is incredibly broad, ranging from entirely new methods based on **molecular selfassembly** to developing novel materials with nanoscale dimensions. It also involves clever expansions of traditional device physics. The fascinating part? Materials scaled down to the nanoscale can exhibit **different properties** than their larger counterparts, opening up entirely new applications. **Particle technology and nanotechnology often intersect** when researchers need to determine the **zeta potential (surface chemistry)** and **particle size distribution** of these nanoscale materials. Here are just a few examples of fascinating nanoscale particles that have garnered significant interest:

Stability Studies

To assess the **stability** of the new BNS3-loaded topical gel, we conducted a 90-day study. Samples were stored in a programmable environmental test chamber (Parameter Generation and Control) under both room temperature (25°C) and accelerated conditions (50°C, 75% relative humidity). Following the 12-week

evaluation, we measured the gel's **particle size and drug release** to determine its stability. **Statistical analysis**

All data were analysed using **One-way Analysis of Variance (ANOVA)** with **Dunnett's test**, with statistical significance set at a p-value less than 0.05. Each sample was tested in triplicate, and results are presented as the mean ± standard deviation.

The synthesized nanospheres (BNS1-BNS4) showed **entrapment efficiencies ranging from 51.2 ± 0.67% to 78.4 ± 0.87%**. We observed that **higher particle size and increased EC polymer concentration led to greater drug entrapment**. Conversely, smaller particle sizes resulted in lower entrapment efficiency, likely due to their larger surface area increasing the potential for drug escape from the porous nanospheres. For water-insoluble drugs, their insolubility drives maximum entrapment within nanocarriers. Furthermore, increased **drugpolymer interaction and miscibility in organic solvents** contribute to higher drug entrapment, with **increased EC polymer concentration consequently enhancing drug entrapment in the nanospheres**.

Evaluation of Optimizes

NS Scanning electron microscopy developed nanosphere-based topical gel was optimized to have a skin-compatible pH of 6.04. Its consistency was determined to be 36,741 ± 0.76 cps, with a spread ability of 14.67 ± **0.76 g-cm/sec**. Crucially, the gel achieved an impressive **drug content of 99.87 ± 0.65%**. Rheological investigations confirmed its **shear-thinning nature** and a viscosity of 35,00040,000 cps, suitable for topical use. These findings indicate the topical gel is **easy to apply** to the skin, and the active drug is **homogeneously distributed** throughout the Nano sponge formulation.

Drug diffusion and release kinetics

In vitro drug release synthesis, resulted in the initial burst release followed by continuous drug release. The drug desorption from the NS surface was what caused the initial burst effects to occur 0.5 hours. The porous matrix that EC created provide for prolonged and gradual release of topical gel. **Stability studies**

While still within the nanoscale range, the **particle size** slightly increased from **543 ± 0.67 nm before stability testing to 568 ± 0.37 nm afterward**. This observed difference could be influenced by the storage conditions of the nanospheres within the gel formulation.

Stability data of optimized Formulation

To identify the best formulation, trial batches were rigorously evaluated using the **identical criteria applied to the prototypes**. These comprehensive assessments covered **appearance, pH, viscosity, homogeneity, particle size, drug content, in vitro drug release, skin irritation, spread ability, extrudability, rheological properties, and stability**. From this detailed analysis, **Batch A emerged as the optimized formulation**, prompting the development of an experimental design. **Conclusion**

We successfully developed a **nanogel formulation**, demonstrating its effectiveness and superiority as a carrier for transdermal and topical applications. All critical parameters of the nanogel were optimized, including its **appearance, pH, viscosity, homogeneity, particle size, drug content, in vitro drug release, skin irritation, spread ability, extrudability, rheological properties, and stability**.

Administering the nanogel topically offers significant advantages over oral methods, such as **avoiding first-pass metabolism** and maintaining **consistent plasma drug levels**. Each formulation initially showed a rapid drug release, likely due to partial gel formation early on. However, once the gel fully formed, the release rate significantly slowed. The release profile in the diffusion cell's donor compartment revealed a clear inflection point, indicating the transition from gel formation to diffusion through the membrane. This slowdown in drug release as the formulation solidified into a gel suggests the gels can **effectively retain tea tree oil over time**. Furthermore, manufacturing this nanogel formulation proved to be **more efficient and affordable** compared to producing oral dosage forms.

Acknowledgement

Guide Associate Professor Dr Rakhee Kapadia Jain and HOD Dr NPS Senger deserve praise for their generosity in providing assistance and support.

We extend our sincere gratitude to the **Management, Director, and staff for their invaluable assistance and support.**

Conflict of interest

There is no conflict of interest.

References –

1. Nanotechnology and Nanoelectronics Materials, Devices, Measurement Techniques by D.P. Kothari.
2. Introduction to Nanoscale Science and Technology by Massimiliano Di Ventra, Stephane Evoy and James R. Heflin.
3. Nanoscience for the Conservation of works of Arts by Baglioni
4. ScienceDirect
5. PubMed
6. Kumar S, Parchuri DB, Kumar GSS, Goli D & Karki R.. Formulation and evaluation of nanoparticulate drug delivery system of acyclovir for. World Journal of Pharmacy and Pharmaceutical Sciences. 2013;2(6), 5602–17.
7. Ravikumar ATRP. Polymeric nanoparticles based topical drug delivery. Asian Journal of Biomedical and Pharmaceutical Sciences. 2015; 47(5), 5–12.
8. Basha BN, Prakasam K, Goli D & College BMR.Formulation and evaluation of Gel containing Fluconazole-Antifungal Agent. IJDDR. 2010;3(4), 109–128.
9. Mutalik S, Udupa N. Glibenclamide transdermal patches: physicochemical, pharmacodynamic and pharmacokinetic evaluations. J. Pharm. Sci. 2004; 93: 1577–94.
10. Saroha K, Singh S, Aggarwal A, Nanda S. Transdermal Gels- An alternative vehicle for drug delivery. Int.J. Pharm. Chem. Biol. Sci. 2013; 3(3), pp495-503.
11. Indora N, Kaushikm D. Design , development and evaluation of ethosomal gel of fluconazole for topical fungal infection. Int J Eng Sci Invent Res Dev. 2015;I(Viii):280.
12. Briede RH. Application of Carbomer water gel 1%. Pharm Week. 1983; 118(9):
170-4
13. Indora N, Kaushikm D. Design , development and evaluation of ethosomal gel of fluconazole for topical fungal infection. Int J Eng Sci Invent Res Dev. 2015;I(Viii):280.