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Nanoparticles in Cosmetics: The Safety and Hidden Risks

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ABSTRACT: Nanotechnology is a prime example of innovation in the world of research and development since it promotes product effectiveness by incorporation of innovative techniques. The cosmeceutical sector is increasingly turning to nanotechnology to address some of the shortcomings of conventional approaches. Cosmetics are the personal care product category that is expanding the quickest, and the utilisation of these items has expanded significantly in recent years. A class of hair, skin, lip and nails care products called nanocosmeceuticals can be used to treat phototoxicity and ageing, wrinkles, hyperpigmentation, dandruff, hair loss, etc. Nanotoxicological investigations have raised concerns about the consequences of increasing nanoparticle incorporation into cosmeceuticals due to nanoparticles' capacity to permeate skin and lead to adverse health effects. Challenges in the cosmetic industry include ensuring the safety and biocompatibility of nanoparticles, understanding their long-term effects on human health, and addressing potential environmental impacts. Careful regulation and continuous research are necessary to address these challenges and ensure the responsible and sustainable use of nanoparticles in cosmetics. The primary areas that are intriguing in the research of nanotechnology in cosmeceuticals involve the variety of unique carriers employed for cosmeceutical administration, the positive and negative aspects of commercial formulations, toxicity, and nanocosmeceutical constraints. The primary aim of this article is to present the positive and negative aspects of employing nanoparticles in cosmetics.

Keywords: Nanocosmetics, Nanoparticles, Nocosmeceuticals, Risk and Benefits, Regulatory Guidelines, Nanomaterial.

INTRODUCTION

The market for cosmetics is anticipated to be significantly impacted by nanotechnology, which is generally recognised as the biggest technological breakthrough of the twenty-first century. The word "nanotechnology" is a combination of the words "technology" with the Greek letter "nano," which stands for "dwarf". As it turns out, nanotechnology is the technology and science used to make or deal with particles ranging in size from one to 100 nanometers (Tile *et al.*, 2016). After 1959, the implementation of nanotechnology in the field of cosmetic including helathcare and dermatogical formulations has been employed widely (Clunan *et al*., 2014). It encompasses a fusion of chemistry, physics, engineering, biology, and other scientific disciplines. In the 4000 BC era, the Romans, Greeks, and Egyptians all proclaimed the use of nanoparticle based technology, including the idea of nanomaterials-based colours preparations for hairs (Nasrollahzadeh *et al*., 2019). Through its manufacturers and investigators, the cosmetics business has embraced nanotechnology, and it is subtly but gradually extending its horizons to meet customers' rising need to seem elegant and beautiful. Cubosomes, nanoemulsions, curling tongs, razors, dendrimers, anti-aging products and sunscreen represent some of the nanostructured particles employed in cosmetics (Martel-Estrada *et al*., 2022).

Since many centuries ago, nanomaterials have been utilised in the manufacture of cosmetics. Women have utilised silver and gold nanoparticles as nail colours. Anti-aging products incorporating gold-silver nanoparticles were also in use during the middle Ages (Dini & Mancusi 2023). However, there has been a substantial growth in the usage of nanoscaled materials in the production of cosmetics in recent years. This review focuses on the forms of nanomaterials used in cosmetic based industry by the majority of companies, and also any potential risks they represent to both the mankind and the nature.

COSMETICS AND NANOTECHNOLOGY

A normal adult makes use of 9 cosmetic products every single day. Without uncertainty, cosmetics is the most frequently used products across the world. They are so tempting because they may fulfil a man's intrinsic need to look well and keep youth (Farwin & Ruzaik 2021). Cosmetics refer to beauty-enhancing products or

substances applied to the body, specifically the skin, hair, or nails, aiming to enhance or modify one's physical appearance. These products serve various purposes such as cleansing, moisturizing, enhancing beauty, and safeguarding the external features of the body (Salvioni *et al*., 2021). The realm of cosmetics includes a diverse array of items like makeup, skincare creams, lotions, perfumes, hair care products, and nail polishes, among others. Their purpose is to augment aesthetic attractiveness, encourage self-care practices, and elevate overall grooming and personal hygiene standards.

A number of products for personal care are under a broad spectrum topic of cosmetics. They are generally classified as below (Effiong *et al*., 2020).

1. Cosmetics for skin care, such as moisturising and cleansing products.
2. Hair-care cosmetics such as aesthetic agents, hair colours, conditioners and shampoo may be used.
3. Makeup for the face, comprising lipstick, powder, mascara, and foundation.
4. Nail care goods, such as nail polish and paint removers.
5. Items with a fragrance, including cologne, aftershave, deodorants, and fragrances.
6. Sunscreens and other UV protection measures.

This idea makes it clear that cosmetics are not the same as medications. However, certain cosmetic products are referred to as "cosmeceutical" goods because they may include substances that have a biological impact, a mild therapeutic effect, or advantages similar to those of drugs on the skin.

Skincare scientists, medical professionals, product makers, even writers of academic or cosmetic studies have used this word to encourage customer endorsement of promoted cosmetic items and cosmetics indentification. However, the terms "cosmeceutical" and "cosmetics" are used synonymously in this article. Nanocosmeceuticals are cosmetics made using nanoscale ingredients. Products for caring for the nails, hair, lips, and skin contain a variety of nanocosmeceuticals.

FORMULATIONS OF NANOPARTICLES AS A COSMETICS

Nanomaterials are compounds with at least one nanometer-sized size and distinctly distinct physical and chemical attributes. These substances have been used often for a very long time in the cosmetics sector. Nanomaterial-based cosmetics offer better advantages than micro sized products. Large surface areas of these particles enable for excellent bioabsorption, efficient distribution across the barriers, bioavailability and prolong effects of the content. Care should be taken with the therapeutic concentration to prevent the associated toxicity (Biswas & Wu 2005; Biswas *et al.*, 2023).

Each of the many different shapes and sizes of cosmetic nanomaterials has a unique set of properties that dictate the kind of cosmetics they are best suited for. Fig. 1 illustrates several Nano-based formulations employed in the cosmeceutical industry (Ahmad *et al.*, 2018).

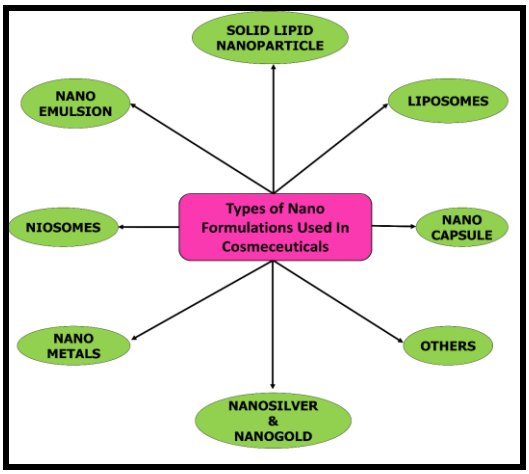

Fig. 1. Types of Nano-Formulations used in a cosmetics.

Liposomes. A sphere-shaped vesicle called a liposome consisting membrane comprised of a bilayer of phospholipid and cholesterol. Liposomes are simple tiny vesicles that completely surround an aqueous volume with a lipid-based membrane (Sharma *et al.*, 2018). It is feasible to introduce hydrophilic drugs into the aqueous compartment and lipophilic drugs into lipid bilayers due to the type of structure. The lipid bilayer can combine with the cell membrane to deliver the liposome contents and target the active components (Shubhrajit Mantry *et al*., 2023). Because liposomes and the epidermis share comparable lipids, they can enhance cutaneous medication delivery while minimising systemic absorption (Çağdaş *et al*., 2014).

For cosmetic items, liposomes aid in anchoring active substances to the surface layers of skin. Detached liposomes possess occlusive properties that can elevate and sustain skin hydration, consequently strengthening the skin's barrier mechanisms. Liposomal vesicles increase medicinal product bioavailability at the location, lowering the dose to administer hence, the risk of adverse effects such irritation and stains that are dose-dependent (Van Tran *et al.*, 2019).

Nano-metals. Due to their high effectiveness and antibacterial qualities, nanometals like nanosilver and nanogold are used in toothpastes and deodorants. Since their widespread application in numerous sectors, these materials have a high market value when compared to other nanoparticles (Abbasi *et al.*, 2020).

Solid lipid nanoparticles (SLNS). SLNs are nanoscale droplets containing lipids that have been stabilised using surface active agents (SLNs). These nano-sized structures have the ability to prevent degradation of the encapsulating active substances. Additionally, SLNs may be utilised to create cosmetics with regulated distribution and to increase the skin penetration of cosmetic active components. Additional benefits of SLNs have been demonstrated, including as ability to improved moisturization and nourishment the skin (Arora *et al.*, 2012).

Nanoemulsions. Nanoemulsions refer to evenly dispersion of nano-sized droplets of one liquid phase into the other continuous phase. These droplets have a large surface area, which makes them suitable for

carrying active ingredients in cosmetic products (Jaiswal *et al*., 2015). These components are considered safe for use in cosmetic manufacturing. Due to their extremely small droplet size, nanoemulsions are highly efficient, stable, and transparent (Aziz *et al.,* 2019).

Nanocapsules. The field of cosmetics greatly benefits from the significant role of nanocapsules. These minute structures, typically ranging in size from 10 to 1000 nanometers, offer a wide range of advantages when incorporated into cosmetic formulations. They function as carrier systems, enclosing active ingredients and safeguarding them against degradation, thereby improving their stability and availability for the desired purpose (Singh & Sharma 2016). Nanocapsules also facilitate controlled release of these ingredients, ensuring a gradual and sustained effect. The ability to regulate the release of ingredients allows for precise delivery and prolonged efficacy. Furthermore, nanocapsules promote the penetration of active compounds into the skin, intensifying their therapeutic effects. In summary, the incorporation of nanocapsules in cosmetics showcases their potential to enhance product performance and attain the desired cosmetic results (Kothamasu *et al.*, 2012 ; Rosset *et al*., 2012).

Niosome. Niosomes serve as colloidal vesicular carriers employed in drug delivery, comprising biodegradable and safe non-ionic surfactant vesicles. Compared to other colloidal carriers, niosomes offer greater cost-effectiveness and stability. They find application in the controlled and precise administration of drugs through various routes such as oral, topical, parental, and ocular (Witika *et al.*, 2021). The introduction of niosomes to the cosmetics industry dates back to the 1970s, and in 1986, Lancome introduced a niosomal lotion targeting signs of aging. Niosomes have a broad range of uses, including hemoglobin delivery, cancer treatment, oral administration of peptide drugs, leishmaniasis treatment, ocular drug delivery, cosmetics, and as carriers for cutaneous drug delivery (Mawazi *et al.*, 2022).

Globally, nanosilver accounts for approximately 12% of the total nanosized particles employed in cosmetics. Metallic nanoparticles less than 100 nanometers are commonly referred to as mineral nanoparticles (Nohynek *et al*., 2007). Colloidal silver or silver nanoparticles are frequently employed as preservatives in a variety of personal care products, including shampoos, toothpaste, and remedies for acne. This is due to their efficacy against a range of microorganisms and possession of antibacterial properties, rendering them a suitable choice for combating infections (Ong & Nyam 2022). Extensive research has been conducted on nanosilver and its derivatives to harness their unique antifungal and antibacterial properties. The antimicrobial effects of silver nanoparticles are believed to be attributed to the release of silver ions. While gold nanoparticles on the opposite, offer potential for use in cosmetics due to their ability to deliver and release drugs efficiently. The integration of these nanoparticles with cosmetic ingredients enhances the overall quality of the final product. Their functionalization through thiol linkages is often straightforward. Nano gold is commonly incorporated into toothpastes and other readily availablepersonal care products, facilitating effective dental hygiene practices (Kim *et al.,* 2007; Gajbhiye & Sakharwade 2016).

Cosmetic benefits, safety and health concerns. The unique properties of nanoparticles used in cosmetics can be both advantageous and detrimental. While they offer enticing cosmetic benefits, they also have the potential to negatively impact the body's systems. This is due to the rapid changes in particle properties at the nanoscale, which raises concerns about safety and health. The safety of nanomaterials in terms of toxicity is still not well understood, posing a significant apprehension about the use of nanosized particles in cosmetics. It raises concerns regarding their potential to enter the bloodstream during production or application and the potential adverse effects that may result from such exposure (Subramaniam *et al.,* 2019). In the United States, the need for nanomaterials safety was emphasized when the FDA introduced nanotechnology guidelines for regulatory consideration, focusing on the safety and integrity of cosmetic products. To evaluate the safety of nanoparticles in cosmetics, the FDA necessitates two key pieces of information. Firstly, it is crucial to provide details about the properties of the substance, especially in its nano-sized form. This includes details about the materials used, finished cosmetic products, biological interactions, and characterization of any associated contaminants, as nanoparticles exhibit various physicochemical properties. Having precise and accessible information of this nature can significantly aid in addressing concerns related to poisoning, pollution, and allergies. The second component involves toxicological data specific to the evaluation of nano-sized cosmetic products should encompass a comprehensive assessment of acute, chronic, and sub-chronic systemic toxicity, as well as potential skin irritation, allergies, photo irritation, and photoallergic reactions (Effiong *et al.,* 2020). Additionally, cumulative exposure to nanoparticles from similar products or prolonged usage of specific items presents a potential toxicological risk. Gathering additional data is necessary to evaluate genotoxicity, fetal toxicity, carcinogenicity, and reproductive health effects (Nohynek *et al*., 2010). It is important to note that nanocosmeceuticals come with certain drawbacks, as illustrated in Fig. 2.

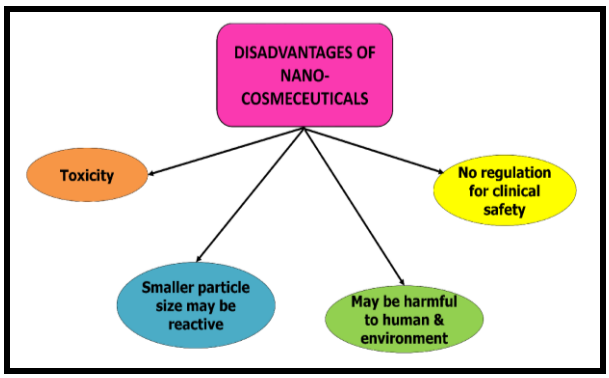

Fig. 2. Disadvantages of Nano Cosmeceutical (Kaul *et al*., 2018).

Toxicity of using nanomaterial's in cosmetics. The use of nanomaterials in cosmetics poses significant risks. Various studies have provided evidence of unintended penetration of nanoparticles into the skin and bloodstream. Sunscreen creams containing nanoparticles such as titanium dioxide and zinc oxide, ranging in size from 10 to 200 nm, have been shown to accidentally penetrate intact skin, causing harm to living tissue (Raj *et al.,* 2012). Neurotoxic effects have been observed in experiments where zinc oxide nanoparticles were tested on mouse neural stem cells. Furthermore, titanium dioxide nanoparticles have been found to exhibit cytotoxicity (Subramaniam *et al.*, 2019). Recent research has indicated that titanium dioxide nanoparticles can trigger autophagy and necrosis in sertoli cells, negatively impacting spermatogenic cells and testicular morphology in Zebra fish (Kotil *et al.,* 2017). Factors such as eczema, acne, wounds, psoriasis, and UV exposure enhance the penetration of these nanoparticles into deeper layers of the skin and the bloodstream. Workplace exposure to nanoparticles can occur during the production process, as well as when using, recycling, or disposing of products that contain nanoscale substance. Nanomaterials pose a greater danger than micronized particles due to their increased ability to enter living cells and tissues.

People can be exposed to nanomaterials through inhalation, ingestion, and absorption through the skin. Environmental concerns may also arise from the manufacturing, use, and disposal of nanomaterials in large quantities, leading to their release into the air, water, or soil. The presence of antibacterial nanoparticles, for example, can disrupt the natural ecosystem's beneficial bacterial system. Additionally, certain nanomaterials can bind to airborne pollutants like cadmium or petrochemicals and transport them over long distances. Therefore, the potential risks associated with nanocosmetics should be carefully considered in terms of their creation, usage, and disposal (Effiong *et al.,* 2020).

Regulatory Features of Nanocosmeceuticals. Since there are currently few toxicity studies, the rapid advancement of nanotechnology in the cosmetics industry has prompted worries about safety issues and its possible hazardous effects, particularly on human health. The hazardous effects are as below (Gupta *et al*., 2022; Mohd-Setapar *et al.*, 2022)

1. Nanoparticles may travel through the human body and pass through membranes with ease due to their small size and structure. They may then enter tissues, organs, blood, and cells, which allows them to harm or kill cells.
2. A higher surface-to-volume ratio is related to the modified physicochemical characteristics of nanomaterials. In comparison to bigger particles, high reactivity and biological activity may be seen, which raises free radicals, leads to oxidative stress and skin irritation, both results in toxicity to the human system.
3. In order to assure their stability, nanocosmetics employ high surfactant concentrations, however surface active chemical exposure may cause serious skin irritation by impacting cells in the deep skin layer;
4. Inhalation is a typical method of nanoparticles administration, which might result in the particles entering the lungs, moving to the brain, and entering the nervous system, blood, and organs, causing a variety of negative consequences.

Ingestion and skin contact are two more ways to be exposed. In order to address the safety concern of nanocosmetics and support the cosmetic business as well as academics, researchers, etc., a number of regulatory agencies have developed recommendations. Significant recommendations from key bodies are collected in Table 1. To avoid any negative side effects with the application of nanocosmeceutical products, these recommendations needs to be followed (Alshawwa *et al.,* 2022; Mohd-Setapar *et al.,* 2022).

Table 1: Main regulations highlighting the safety of nanomaterial usage in cosmetics.

Regulatory Agencies	Rules Guidance	Guidance Document	Key Elements
Food and Drug Administration (FDA), United States	Food, Drug, and Cosmetic Act	Industry Safety Guidelines for Nanomaterials in Cosmetic Products	Several crucial criteria should be taken into account when making recommendations for safety assessments of nanomaterial's: - Physical-chemical attributes - Exposure route - -Toxicological information
European Medicines Evaluation Agency (EMEA), European Union	Council Directive 76/768/EEC	Scientific Committee on Consumer Safety (SCCS)	Provide specific guidance on safety evaluationof nanomaterials used as cosmeticingredients includes: - Physicochemical characterization - Exposure assessment - Hazard identification and dose-response characterization - Risk assessment
International Cooperation on Cosmetics Regulation (ICCR)	-	Report of the ICCR Working Group—Safety Approaches toNanomaterials inCosmetics	Provide experts' view on the key safety highlighting: - Existing risk assessment pattern - Important physicochemical parameters of raw materials - Effect of formulation should be considered, as the bioavailability and toxicological profile of active compounds.

CONCLUSIONS

Nanotechnology is an exceptionally advanced field of research, considering distinctive characteristics of nanoparticles that are useful in the cosmeceutical industries. The cosmeceutical sector based on nanotechnology is growing rapidly and, being the most promising technology at the present time, has the potential to revolutionise the cosmeceutical market. As is widely known, a large number of items on the market include nanoparticles in some capacity. We need to investigate many of these materials and record their health consequences, especially when applied to the skin, in order to assess the toxicity of these particles, which is still a matter of much discussion and misunderstanding. Before being approved for usage, all nanoparticles used in the production of cosmetics must undergo practical application. After this test, the safe substances that may be used to make these cosmetics must then be legalised, together with adequate product labelling and effect control. Additionally, consumers who use cosmetics using nanoparticles must immediately report any unusual interactions to the proper authorities so that the market's secure products may be regulated and supervised for safety purposes.

FUTURE SCOPE

The utilization of nanoparticles in cosmetic products presents immense potential, transforming their efficacy. Due to their minute size, nanoparticles bolster skin permeation, enable precise administration of active constituents, and enhance product durability. Their adaptable characteristics facilitate advancements in sunscreens, anti-aging creams, and formulations for skin brightening, delivering elevated skincare advantages to consumers.

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Conflict of Interest. None.

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