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REVIEW ARTICLE **OPEN ACCESS**

A Review on Recent Nanotechnological Advances and Developments in Cosmetics

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ABSTRACT
The role of cosmetics in contemporary culture is fast changing, with their use being considered as a necessary component of personal wellness. The different types of nanocarriers that are used in cosmetics such as cubosomes, liposomes, hydrogels, dendrimes, nanoemulsions, nanocrystals, microemulsion, and solid lipid nanoparticles. Nanoparticles-based cosmetics, also known as nanocosmeceuticals, have broadened the scope of cosmetics' applications in treating wrinkling, dehydration, and inelastic skin associated with age, as well as scattered hyper pigmentation. Nanoscale compounds are used by cosmetic producers to provide improved UV protection, deeper skin penetration, long-lasting effects, increased colour, finish quality, and many other benefits. The review's goal is to provide an update on the present state and trends in research and industrial development connected to the use of nanotechnology in cosmetics, as well as to forecast where the field might go in the future.
Key words: *Cosmetics, Skin care, Nanotechnology.*

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INTRODUCTION

Cosmetics are products that are used to clean, decorate, and enhance the appearance of the human body. Demand for the cosmetic products over worldwide is increasing day by day. One of the most popular categories was skincare, which constituted for around 42% of the international market. In 2020, hair care items accounted for another 22%, while make-up accounted for 16% [1]. The worldwide cosmetic and skin care market is expected to reach $716 billion by 2025, most of that value attributed to the implementation of novel and/or innovative products and technology [2]. Over the years cosmetics gained much more attention, peoples are using them regularly but because of the drawbacks like efficacy, stability, safety and durability associated with them it was necessary to seek advancement in the industry [3]. Nanotechnology has wide applications in various fields. Nanotechnology is increasingly being used in the field of cosmeceutical to overcome the drawbacks associated with conventional products [4].Various nanocarriers are used to formulate cosmeceutical products. Improved skin penetration, regulated and prolonged drug release, higher stability, site-specific targeting, high encapsulation efficiency, increased colour, long-lasting action, and completed quality are all advantages of these unique nanocarriers. Nanoparticles are becoming more popular in cosmetics due to their high surface-to-volume ratio, which allows for better skin penetration [5].

Skincare products are cosmetics that are used on the surface of skin. Their efficacy is determined by the chemicals utilised and the method employed to make them. Generally skincare includes protective, cleansing, hydrating, moisturizing, soothing and firming type of products[1]. Nanotechnology in skincare can bring lots of benefit over its use. There are several marketed preparations in which nanocarriers are used. Concealers, foundations and mineral foundations sold by well-known brands like (Clinique, Clarins, L'Oréal, Revlon, The Body Shop, Max Factor, Lancôme Paris and By Terry). Anti-aging skin care products are there from L'Oreal brand containing Antioxidants like Pro-retinol, Panthenol/Vit-E into nanocarriers like Nanosomes, Nanocapsules. A well-known cosmetics firm, L'Oréal S.A, has filed nearly seven patents for the use of nanoparticles in cosmetic compositions [5].

Advantages of use of Nanocarriers used in cosmetic preparations:

- They increase's surface area of the product.
- They enhance product solubility.
- Increases rate of absorption and penetration across the skin surface.
- Enhances stability, safety and increases its durability also the shelf life.
- Improves formulation texture.

As a result, the current review paper provides present viewpoints on nanotechnology in cosmetic preparations, as well as a description of potential challenges. A brief summary of skin morphology, anatomy, and physiology is offered to help us better understanding about the advantages and disadvantages of the topical skin route[6].

Anatomy & physiology of skin

The skin is the body's biggest organ, accounting for about 15% of total adult body weight. It serves a variety of important roles, including protection against external physical, Biological, chemicals well as prevent extreme water loss from the body and it plays a role in thermoregulation. The integumentary system include derived organ (i,enails, hairs etc).The skin is made up of top layer called epidermis, middle layer called dermis & bottom layer called hypodermis. Epidermis composed of keratinized epithelium and which produced keratin (fibrous protein) and it play protective role[7].

Dermis which is thickest middle layer contain highest amount of collagen and middle layer present on the panniculus and the thickness of the layer differ significantly based on their location on the anatomy of the body. The dermis is located on the panniculus, a subcutaneous tissue that contains little lobes of fat cells known as lipocytes. The thickness of these layers varies greatly depending on where they are located on the body's anatomy[8].

1) Epidermis:- The epidermis is thin, stratified, avascular superficial layer of the skin. The epidermis regenerates with new cell every 28 days. Different type of layers of epidermis that are:-

- **Stratum basale(or stratum germinativum):-** Deepest layer of the five layers of the epidermis. Single layer of columnar or cuboidal basale cell. Stratum germinatum necessary for the regeneration of the layers of epidermis.
- **Stratum spinosum(or prickle cell layer):-** Layer composed polyhedral keratinocytes. The layer of epidermis found between stratum basale and stratum granulosum. Stratum spinosum layer helps to make skin strong and flexible.
- **Stratum granulosum(or granular layer):-** Is the thinnest layer of epidermis found above stratum spinosum and below the stratum corneum. Stratum granulosum act as waterproof barrier that prevent fluid loss from the body.
- **Stratum lucidum (clear layer):-** Is a thin , clear layer of the dead skin cells of the epidermis and present only on palms and soles.
- **Stratum corneum:-** Outer layer of the skin and act as a barrier between the body and the environment and also prevent excessive loss of water.

Cells of Epidermis:- Two major type of epidermal cells that are Melanocytes(5%) and Keratinocytes (90%)

- **Melanocytes (Melanin producing neural crest derived cells)**:- Present in the deep, basal layer (stratum germinativum) of epidermis. Melanocytes contain melanin gives colour to the skin and hair and it also protect damaging of the body from ultraviolet sunlight. More melanin results in darker skin color.
- **Keratinocytes:** - 90% of the cells in the epidermis are ectodermally derived keratinocytes. Keratinocytes are produced from epidermal cells in the basal layer. It produce keratin and fibrous protein which act as skin's protective barrier function [8][10].

2) Dermis:- The dermis is the internal layer of two primary layers of the skin. Dermis has connective tissue, oil and sweat glands, blood vessels, hair follicles. Dermis is vascular and its thickness varies from 1 to 4 mm. Dermis is divided into two layers that are:-

- **Papillary layer:-** Defined by rate ridges(I,e. papillae).Layer has finger like structure and which extend into upper epidermal layer. Upper thin Papillary layer contains thin collagen fibres, cytoplasm, blood capillaries and sensory nerve endings. Papillary layers regulates temperature and supply nutrient to select layers of the epidermis.
- **Reticular layer:-** Is the deeper, thicker and made up of thick collagen fibers. Reticular layer is denser than papillary layer and providing structure and elasticity to the skin [8][10].

3) Subcutaneous Tissue:- Subcutaneous tissue present below the dermis and is not part of the skin. Subcutaneous tissue also known as the hypodermis contains larger blood vessels and nerves and it act as as insulator to help regulate body temperature. Subcutaneous tissue often discussed with the skin because it attaches the skin to underlying tissue such as muscle and bone[7].

Skin Appendages: - Skin Appendages includes Hair, Nails, Glands (Sebaceous, Apocrine and Eccrine). Two major types of glands associated with skin are Sebaceous and sweat (apocrine and eccrine) glands. The apocrine glands in the skin are in the armpits, sclap region. The skin's apocrine gland called smell gland and their excretion have distinct odour. It is tubular spiral gland covered all body area mainly on the bottom of the foot. Eccrine glands help to maintain homoeostasis, by stabilizing body temperature [7].

Nanomaterials used in cosmetics

Several nano-based products have been created, utilising a wide range of nanomaterials with various compositions, shapes, and sizes. These were chosen primarily for their potential to overcome common cosmetics restrictions by increasing penetration, improving ingredient stability, managing the release of active chemicals, and acting as active agents themselves.

Inorganic Nanoparticles:

As opposed to organic nanoparticles, inorganic nanoparticles are non-poisonous, hydrophilic, nanostructur, and very stable. TiO2 is mostly used inorganic nanoparticles in sunscreens, as it has significant amount of sun protection factor (SPF) in nanoscale, making it more active and having superior cosmetic outcome due to its transparency, in comparison of TiO2 pigment. Starting around 20 nm, the commonly used UV filters in sunscreen are ZnO and TiO2, who has better dispersion and a more appealing appearance [11].

Silica (SiO_2):

The cosmetic industry is interested in silica nanoparticles because of their hydrophilic surface, which promotes prolonged circulation, and their inexpensive production cost. Nano Silica is used in cosmetics to improve its efficacy, texture, and shelf life. It functions as an absorbent and anti-caking agent[12] [13].

Nano-Organic Materials:

Tris-Biphenyl Triazine is a highly distinct, powerful, effective and photostable nano-organic material, making it an ideal and absolute material in sunscreen composition[14]. Tris-Biphenyl Triazine (nano) is a broad-spectrum UV filter that can be used in sunscreen and anti-aging products [15].

Gold and Silver Nanoparticles:

Apart from their many applications, gold and silver nanoparticles also exhibit antibacterial and antifungal characteristics. Cosmetics such as deodorants and anti-aging lotions contain gold and silver nanoparticles. Silver nanopaticles have been shown to be effective growth inhibitors in a variety of bacteria. In a variety of applications, silver and silver-based compounds are utilised to limit bacterial growth [16].

Nanoliposomes:

Nanoliposomes are biodegradable and biocompatible, making them a very flexible cosmetic ingredient category. They're utilised to increase skin permeability and moisturise the skin by acting as protective carriers for active substances [17].

Liposome:

Liposomes are a minute spherical sac of phospholipid molecules enclosing a water droplet, especially as formed artificially to carry drugs or other substances into the tissues**.** Size**.** 200nm upto several nm [18].

Liposome in cosmetics:

- Liposomes ambushes cosmetic chemicals, which may be hydrophilic or hydrophobic, and release their substance at relevant area or targeted spot. As a result, this method may deliver cosmetic chemicals that are poorly soluble [19-20].
- When vitamins are encapsulated with the use of a liposome and supplied to the skin's epidermis to renew it, the stability of vitamin A, E and carotenoids is increased [20].
- Marinosomes help in the healing of many of the skin's inflammatory disorders, and toxicity tests demonstrate that this type of liposome is safe to use on the skin and in the eyes[21].Ultrasomes aid in the detection of harmful UV radiation to the skin and can speed up therapy by up to four times[21]
- When skin is impacted by eczema or injured due to a lack of moisture, so these liposomes can highly interact with lipids, proteins, and carbohydrates present in skin and aid skin to recover to its original state, allowing the stratum corneum to execute its protective role properly [20].

Niosomes:

Niosomes are non-ionic surfactant-based multilamellar or unilamellar vesicles in which an aqueous solution of the solute is entirely encapsulated by a membrane formed by surfactant macromolecules organised as bilayers. Size:0.02-0.10micrometre[22].

Niosomes in cosmetics:

N-acetyl glucosamine niosomes are being developed because penetration to their potential for topical administration of hydrophilic and hydrophobic medicines as well as better skin [23] [24].

• Prepared formulations enhanced the degree of medication localization in the skin, which is required in hyperpigmentation diseases [25].

• Elastic niosomes demonstrated improved penetration into the skin, which would be advantageous for topical anti-aging applications [26].
• Niosomes are suited for skin moisturising and tanning treatments[26].
• Niosomes with additional solubilizers improved ellagic acid absorption into the skin, resulting in higher efficacy of ellagic acid (a powerful antioxidant phytochemical compound with restricted usage due to weak biopharmaceutical characteristics, low solubility, and low permeability)[27].
Cosmetic components can be dissolved or dispersed in aqueous solution and transported within the niosomes, where they can be supplied to a specific location or at a regulated rate[19].

Dendrimers :

Dendrimers represent a class of novel polymers having unique molecular architectures characterized by their well-defined structure, with a high degree of molecular uniformity, low polydispersity and properties that make them attractive materials for the development of nanomedicines.**Size:** 2 to 10 nm[21].

Dendrimers in cosmetics:

- Various cosmeceutical products, such as sunscreen, shampoos, anti-acne creams, and hair-styling gels, include these nanostructures[28].
- Dendrimers have showed promise in delivering dermal preparations effectively through the skin barrier. The skin penetrating capabilities of G4-polyamidoamine dendrimers were initially investigated by Chauhan et al (PAMAM)[28].
- An in vitro study found that pretreatment of skin with PAMAM dendrimers improved the volume and penetration of chlorhexidine digluconate (CHG) into the skin. These discoveries were helpful in terms of boosting treatment efficiency against bacterial skin infections, which makes them valuable in cosmetic formulations[28][29].
- The pre-treatment with dendrimers improves chlorhexidine digluconate penetration through the skin. Encapsulating agents for personal care and cosmetics formulations can include biodegradable polymers such as poly-esters, polysaccharides, poly amidoamine, and poly alkyl cyanoacrylates dendrimers[28][29].
- One of the key properties of dendrimers that makes them suitable for cosmetic compositions is their intrinsic viscosity. Many cosmetic businesses, including Dow Chemical, L'Oréal, Revlon, and Unilever, hold numerous patents on dendrimer-based cosmetic formulations for use in skin, nail, and hair care products[28][19].

Nano emulsion:

They are thermodynamically unstable system consisting of atleast two immiscible liquid phase, one of which is dispersed as a globule in the other liquid phase which is continuous phase. Nano emulsion can be defined as oil in water (o/w) emulsion with mean droplet diameter's ranging from 50 to 1000 nm. Usually the average droplet size is between 100-500 nm [30].

Nano emulsion in cosmetics:

- Nano emulsion allows for a wide range of goods with diverse aesthetic characteristics, richness, and skin feel, such as lotions and crystal transparent gels with varying rheological behaviour[30].
- Nano emulsions have lately gained popularity as prospective vesicles for cosmetic delivery, regulated medicine administration, and enhanced dispersion of active substances in specific skin layers[31].
- This formulation is ideal for reducing transepidermal water loss, increasing skin production, and improving active component penetration [29].
- Nanoemulsion implies that it would be very beneficial for suncare products, as well as moisturising and antioxidant cream [31].
- A proprietary cosmetic technique based on nanoemulsions that aims to improve skin smoothness by increasing active ingredient penetration and dermal cell formation [30].
- Nanoemulsion are acceptable in cosmetics because there is no cause of creaming, sedimentation, flocculation or coalescence that is observed in microemulsions [31][32].

Solid Lipid Nanoparticles:

Solid lipid nanoparticles (SLNs) are sub-micron colloidal carriers ranging from 50-1000 nm, which are composed of a physiological lipid dispersed in water or in aqueous surfactant solution.
They consist of macromolecular materials in which the active component is dissolved, entrapped, or to which the active component is adsorbed or attached[33].

SLN in cosmetics:

- Solid lipid nanoparticles (SLN) are innovative pharmacological and cosmetic active component delivery methods. An in vivo research found that adding 4% SLN to a typical o/w cream resulted in a 31% improvement in moisture retention over 4 weeks[33][34].
- SLN has also been studied as a physical sunscreen and as an active carrier for molecular sunscreens. When opposed to a typical emulsion, the amount of molecular sunscreen might be reduced by half despite keeping the same degree of protection[33].
- Acts as a barrier towards chemical degradation of the medication and the ability to modulate the release of the active constituent [34].

Nanocapsules:

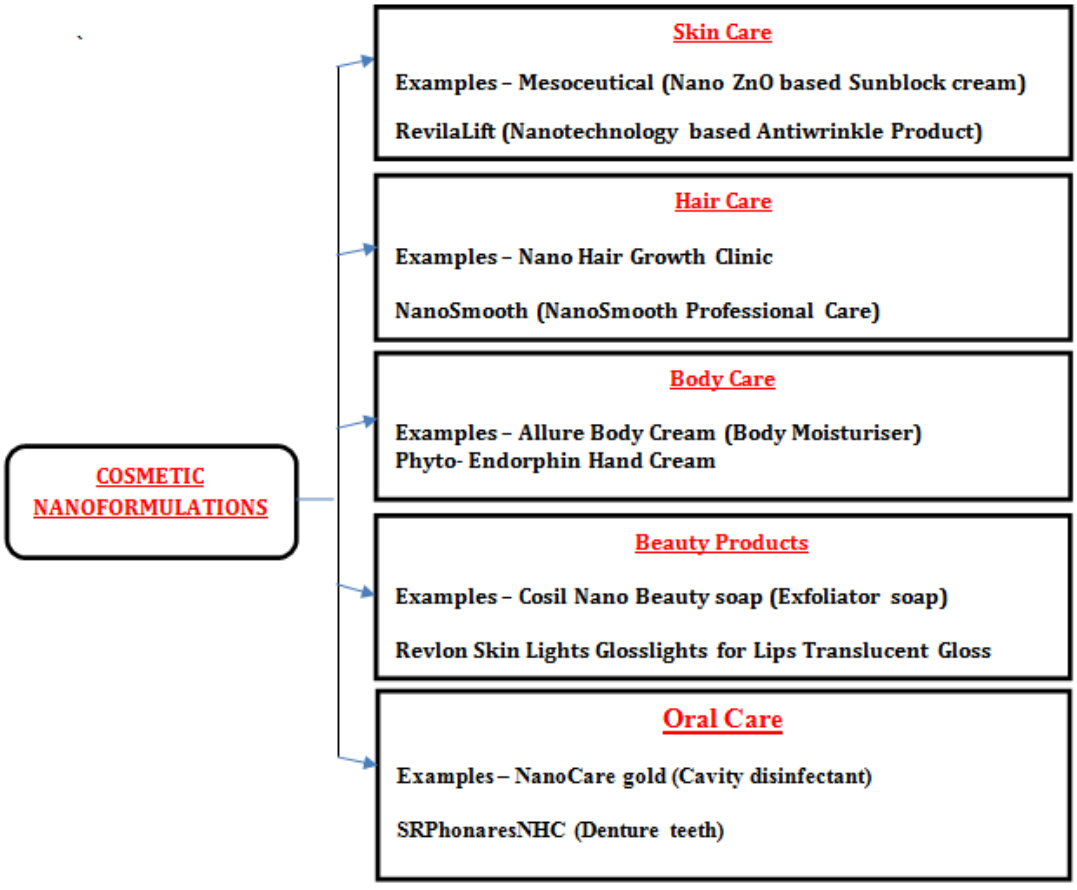
Nanocapsules are vesicular systems in which the drug is confined to a cavity surrounded by a unique polymer membrane, while nanospheres are matrix systems in which the drug is physically and uniformly dispersed [19].

Nanocapsules in cosmetics:

- These colloidal aqueous solutions improve medication stabilization, prolong and regulate drug release, and promote drug adherence to the epidermis in the cosmetics and dermatological applications. Nanocapsules can be used to prevent compounds like UV filters from penetrating the skin or to transfer active agents like genistein to the deep layers of the skin.
- In cosmetic products, nocapsules are used to preserve delicate active ingredients, reduce unpleasant smells, and eliminate incompatibilities between additives. An antiwrinkle lotion with vitamin A nanocapsules that gradually release the active component over time was one of the first nanocapsule-based products available in the market[35].

Types of nanotechnology-based cosmetics

- Nanotechnology offers a wide range of uses in agriculture, food, paints, medicine, and textiles, to name a few. Nanomaterials are widely used in the cosmetic sector for a variety of reasons [36]. As a result of the increased demand from customers, cosmetic formulas with improved performance have been developed [37].
- Retentions, attractiveness, and, most importantly, safety [38].



`**Figure 2:** Cosmetic nanoformulations

Skin Products

Nanotechnology (nano: one billionth) is a new subject in medicine with promising applications in pharmaceuticals for safe and targeted drug delivery. The skin is an excellent platform for studying nanocarriers for medication delivery in topical and dermatological applications[39].The role of cosmetics in contemporary culture is fast changing, with their use being considered as a necessary component of personal wellness [40]. This shows that a thorough investigation of the usage of nanoparticles (NPs) in cosmetics is required [41].Cosmetics' main goal is to keep the skin and its surroundings in good repair while maintaining a reasonable appearance, or curing bodily odours [42].In aesthetic dermatology, new delivery systems and natural nanocompounds, such as chitin nanofibrils for wound healing and nanostructured TiO2 and ZnO sunscreens, are being used successfully [43].

Nanotechnology has been proven the performance of cosmetics in different ways, also it includes :

1) It increases active ingredient entrapment efficiency with dermal penetration [44].
2) It controls drug release
3) It improves physical stability
4) It improves moisturising power
5) It provides UV protection.

UV Filters and sunscreens:

These cosmeceuticals work to protect the skin from the sun's harmful UV radiation, as the name implies. The major chemicals utilised as nanoparticles in UV filters are titanium dioxide and zinc oxide [45]. Despite the fact that various organic replacements are being investigated, these oxides are the most widely used in sunscreens to protect the skin from UV damage [46].

Moisturizing Creams:

Moisturizers, sunscreens, cleansers, and anti aging creams are just a few of the kinds of skin care products available, depending on their intended use. To improve the outcomes of cosmetic bases, a variety of nanocarriers like as nanoparticles, nanoemulsions, niosomes, and SLNs have been used [47].

Because of its interaction at the molecular level, nanotechnology has the potential to revolutionise dermatological diagnosis and therapy. Skin tissue is on a subatomic level. The skin is a fantastic vehicle via which these nanomaterials can be studied for drug administration, both in terms of active component delivery and efficacy [48].

Moisturizers were first introduced as cosmetics to aid in the treatment of skin dehydration, which appeared as drying, scaling, and peeling of the top layer of skin. Moisturizers, which commonly contain humectants, aid in the retention of a thin layer of moisture on the skin's surface, making it appear fresh, supple, and smooth [49].When the skin is moisturised and supple, atopic dermatitis and pruritus can be avoided and controlled. To increase the solubility of chemicals and add shimmer, cosmetic businesses began employing nano-sized materials (e.g. liposomes) as envelopes or carriers of cosmetic compounds. Vitamin E is one such cosmetic component [50].

Anti-ageing products:

Skin thinning, loss of suppleness, dryness, wrinkles, the formation of spots, and the loss of the skin's barrier function are all signs of ageing. Chemical contaminants, ultraviolet and infrared rays, abrasion, and stress is all connected to the ageing process [51]. Skin regeneration and replenishment, on the other hand, are dependent on the quality of collagen (a protein) in the skin. To prevent skin ageing, certain skin creams include proteins produced from stem cells that are encased in liposome nanoparticles that also contain cosmetic components. This enables for optimal protein delivery [52].

Skin cleansers, Disinfectants and Antiseptics:

The skin's initial line of defence (a sebum-sweat mix) can also serve as a harbour for dirt, bacteria, and their metabolic products [53]. Such dirt is a mixture of particle debris trapped from the environment and that from the desquamated stratum corneum, while the metabolic product of the cutaneous bacteria inhabited generates an unpleasant odour, necessitating cleanliness to maintain a healthy skin. Nano silver is found in soaps, toothpastes, wet wipes, and face and body foams that have recently been employed for body washing [54][55].

Future perspectives

Nanomaterials can be employed in a variety of ways in the cosmetics sector.

If the current cosmetic nanomaterial development overcomes the obstacle of nanotoxicity and safety research incentives, we may see new nanotechnology-based products in the market sooner.

These are some of them:-

1) New sunscreens using diamond nanoparticles that reduce UV radiation while also eliminating free radicals produced by UV light. It may be possible to develop a sustained and regulated release of sunscreens with increased moisturising and anti-aging characteristics.

2) Long-lasting hair dyes using carbon nanotubes (CNTs) that provide smoothing, volumizing, and anti-damaging benefits.
3) Dental-care products including fluoride nanoparticles, which cure dentin sensitivity by preventing pain signals from reaching the brain, as well as alumina and rod-shaped hydroxyapatite nanoparticles, which polish teeth effectively while also encouraging long-term remineralization.
4) Anti-aging lotions containing active chemicals contained in synthetic polymer nanoparticles that improve skin permeability [56]
.Cosmetics production is now dominated by nanotechnology, but the industry's future will be shaped by omics science advances, which, when combined with big data analysis and machine learning approaches, will allow us to better assess biological responses to specific cosmetic formulations and bioactive compounds at the cellular and tissue levels [3].

CONCLUSION

Nanotechnology has been extensively researched for its potential to enhance the fields of cosmetology, biotechnology, and medical research. As nanotechnology develops new applications, the formulation and usage of nanoparticulate materials in cosmetics and cosmeceuticals continues to grow.
These nanoparticle-based cosmetics have broadened the scope of cosmetics' uses in the treatment of wrinkling, dehydration, and scattered hyperpigmentation.
The use of nanoparticles in cosmetic preparations is on the rise, and the market for "nano-enhanced" skin treatments is already flooded. However, rather than being content with merely focusing on the commercially feasible aesthetic arena, more research into the health implications of these skin treatments is required. Although there is still much to learn about the toxicity of nanoparticles, it is critical.
Cosmetic regulatory authorities will need to do more than just provide suitable rules and oversight; they will also need to be proactive in screening new and current nanosized compounds in cosmetics to decide whether they are approved or not. These authorities should raise the bar for cosmetics firms in terms of product labelling and post-marketing surveillance. To achieve global coverage, regulatory agencies must collaborate internationally to share information on cosmetic ingredients and their influence on health. Consumers should report any adverse reactions to nanocosmetic goods they use to the proper authorities as soon as they notice them.
According to all indicators, nanoparticle-containing cosmetics will remain relevant, but it is critical that relevance does not come at the expense of health safety.

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