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A REVIEW ON TITANIUM DIOXIDE NANOPARTICLES

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ABSTRACT

Titanium dioxide has great importance in the pharmaceutical industry. The development of nanotechnology led to the development of titanium dioxide nanoparticles with applicable properties in pharmaceutical product manufacturing like sunscreens, foundation creams, coating, water treatment, and food &cosmetics. These nanoparticles are a type of inorganic compound that has grabbed great attention in recent times due to their novel properties and profound applications in various fields. They have been kept under toxicological scrutiny as they have increased exposure to humans and the environment. It was classified as a carcinogen by the international agency for cancer research and the national institute for occupational safety.

Keywords: Titanium dioxide, nanoparticles and safety.

INTRODUCTION

Titanium dioxide (titania, TiO_2) is a chemically inert, semiconducting substance that exhibits photocatalytic properties in light with potential identical to or higher than its band-gap strength. These characteristics provide an extensive variety of uses. For these above reasons, and because of the low price range of the raw material and its processing, titania has received substantial attention over the past decades.

TiO_2 has been categorized in humans and animals as biologically inert and is extensively considered to be a “natural” material, which at least contributes to its incredibly high acceptance by the public. Most TiO2 has been synthesized from the mineral ilmenite, $FeTiO_3$, using the “sulfate” or “chloride” method for nearly 10 decades. The annual international production of titania powder in 2005 has been anticipated to be around five million tons, arising a question about its abundance in the environment. The proportion of nano-sized titanium dioxide is predicted to have been about 2.5 % in 2009, increasing to 10 % by using 2015, with an exponential boom during the last decade. In recent decades, TiO_2 powder has begun to present in many industrial applications, especially because of its potential to confer whiteness and opacity on numerous products like paints, papers, and cosmetics. Its high technological applications originate from its light scattering ability and high range refractive index, which suggests that especially low amounts of pigment are required to obtain a white, opaque coating. The range of light that is scattered depends on the particle size. Numerous technological improvements, primarily based on nano-sized TiO_2, have been delivered that allow its use for antifogging and self-cleaning coatings on glass, for constructing facades, in confectionery, in the plastic manufacturing industries, and so on. Furthermore, TiO_2 is used as a pharmaceutical and food additive. In the united states, it is included in the FDA Inactive elements manual for dental paste, oral capsules, suspensions, drugs, dermal formulations, and non-parenteral drugs. The improved manufacturing of nano-sized TiO_2 has increased concerns about the effects of exposure on human beings and the surrounding environment around the manufacturing site. In this article, we review and discuss the current findings on the potential threat of exposure to nano-sized TiO_2, concerning the particle size and the crystal structure of TiO_2, the path of exposure, and the effect of ultraviolet(UV)radiation on photocatalysis.

PHYSICAL AND CHEMICAL PROPERTIES

The TiO_2 nanoparticles are highly stable and resistant to chemical degradation leading to their usage in different applications. they have a very high melting point of approximately 1800^{0}c. They possess low thermal expansion coefficients providing high resistance towards thermal shock making them suitable for usage in high-temperature environments. The tio_2 nanoparticles have well-known applications in the field of cosmetics and sunscreens. On application to the skin, they can absorb and scatter UV light protecting skin from UV radiation-induced skin damage. they are also used in toothpaste manufacturing as a whitening agent and they have a wide range of usage in various products for an elegant appearance. The TiO2 nanoparticles have a higher surface area as their particle size is less than 100nm. Chemically micro-sized and nano-sized nanoparticles are identical. The isoelectric points of Tio_2 powders are reported to have in the range of p^H 3.5-8. The zeta potential differs over a broad p^H range. The dispersion and disintegration of nanoparticles in liquids depend on zeta potential. This TiO2 in crystalline form occurs in three polymorphic forms they are brookite, rutile, and anatase. In these three rutile is more stable than others. The photocatalysis in the presence of UV radiation results in the formation of reactive radicles which are capable of reacting with surrounding organic substances.

Sl.no	Physicochemical parameter	value
1	Molecular Weight/ Molar Mass	233.38 g/mol
2	Density	4.5 g/cm³
3	Boiling Point	1,600 °C
4	Melting Point	1,843 °C
5	Size	30-50 nm

MARKET SHARE

The global market of titanium dioxide was 16,640.4 million USD in 2019 and is projected to reach 24,092.5 million USD by 2027 exhibiting a 6% CAGR during the forecast period. They have a potential market. They have a potential market in various fields like paper, cosmetics, foods, colorants, textiles, and other industries like the construction industry for paints, coatings, roofing material and floor covering agents and are also used in the production of printing inks. Covid-19 has affected the manufacturing activities of various industries resulting in a slowdown of the market by a reduction in demand for titanium dioxide. The lockdown had a great impact on declining supply chain activities. However, this condition was stabilized after the first wave of the pandemic. In terms of regional market share, Asia-Pacific is currently the largest market for TiO2, accounting for around 45% of global demand. This is primarily due to the large and rapidly growing construction and automotive industries in the region, as well as the increasing demand for consumer goods.

APPLICATION OF TIO2 NANOPARTICLES

Titanium dioxide (TiO2) nanoparticles are used in a variety of applications due to their unique properties, including high surface area, good chemical stability, and high refractive index. Some of the most common applications of TiO2 nanoparticles include

Sunscreens

TiO2 nanoparticles are commonly used in sunscreens because they can absorb and scatter ultraviolet (UV) light, helping to protect the skin from harmful UV radiation.

Coatings

TiO2 nanoparticles are used in coatings for various applications, including to improve the durability and appearance of paints and to provide antimicrobial properties to surfaces.

Catalysts

TiO2 nanoparticles are used as catalysts in chemical reactions, such as in the production of plastics, resins, and chemicals.

Water treatment

TiO2 nanoparticles are used in water treatment systems to remove contaminants and improve water quality.

Food and cosmetics

TiO2 nanoparticles are used in food products as a whitening agent and to improve the texture of certain products. They are also used in cosmetics like foundation creams to provide a matte finish and to improve the opacity of products.

Energy production

TiO2 nanoparticles are used in solar cells and other energy production technologies to improve their efficiency.

Other than the above-stated applications they are used as carriers in cancer therapy for the proper delivery of drugs at the tumor site. Titanium dioxide is extensively used as an opacifier and colourant in medicines due to its multiple functionalities. It is widely used in confectionery, cosmetics and foods, in the plastic industry. It is used in topical and oral pharmaceutical formulations as a white pigment. In pharmaceutical formulations, titanium dioxide is used as a white pigment in film coating suspensions, sugar – coated tablets and gelatin capsules.TiO2 may be admixed with other pigments.TiO2 is also used in dermatological preparations and cosmetics, such as sunscreens.TiO2 is having light scattering properties that may be exploited in its use as a white pigment and opacifier.

ADVERSE EFFECTS OF TiO_2 NANOPARTICLES

1)Titanium dioxide nanoparticles induced Oxidative stress

Nanoparticles exert adverse biological effects by a key mechanism called oxidative stress. It was evident that titanium dioxide induces oxidative stress leading to an increase in the concentration of Reactive oxygen species(ROS) and lipid peroxidation. This leads to the degradation of antioxidants at the cellular level which in turn leads to oxidative DNA damage.

2)Titanium dioxide nanoparticles induced Genotoxicity

Based on several studies it was evident that these titanium dioxide nanoparticles can induce genotoxicity which includes DNA damage, and micronuclei formation which is an indication of chromosomal alterations in various cell lines. the genotoxicity also depends on the size of the nanoparticles. The data obtained from various experimental models of both Invivo and Invitro indicates that nanosized Tio_2 causes genotoxicity via oxidative stress and some secondary mechanisms.

3)Titanium dioxide nanoparticles induced Immunotoxicity

Due to their physicochemical properties and nano-size, the uptake of these nanoparticles by immune cells like monocytes, macrophages, leukocytes, and dendritic cells takes place which can trigger an inflammatory response. The increased concentration of nanoparticles in plasma, blood, and tissues may induce apoptosis and necrosis.

4)Titanium dioxide nanoparticles induced neurotoxicity

Titanium dioxide nanoparticles affect the central nervous system by olfactory pathway. When the nanoparticles are inhaled they cross the Blood Brain Barrier and cause oxidative stress in brain microglia. Which may lead to neurotoxic effects. The inhalation is also related to airway hyper reactivity (AHR) and mil airway inflammation.

BAN OF TITANIUM DIOXIDE NANOPARTICLES

Titanium dioxide nanoparticles (TiO2) are used in a variety of products, including sunscreens, coatings, catalysts, and food products. It has been the subject of increasing scrutiny due to concerns about its potential environmental and health impacts. In recent years, there have been calls to ban the use of TiO2 in certain products. One of the main concerns is that TiO2 particles can be inhaled, which could potentially lead to respiratory problems. There is also evidence that TiO2 particles can accumulate in aquatic environments and have negative impacts on aquatic life. In response to these concerns, several countries and organizations have instituted bans or restrictions on the use of TiO2. For example, in 2020, the European Union banned the use of TiO2 in food products, except for certain limited uses. Similarly, the U.S. Food and Drug Administration has proposed a ban on the use of TiO2 as a food additive, although this ban has not yet been implemented. Other countries and organizations have taken a more cautious approach, restricting the use of TiO2 only in certain products or requiring labeling or warning statements on products that contain TiO2. It is a common and widely used substance that has a variety of industrial and commercial applications, including its use as a food additive and in cosmetics and personal care products.

In 2018, the European Chemicals Agency (ECHA) classified titanium dioxide as a substance that may cause lung cancer when inhaled in the form of very small particles and proposed that it be classified as a "suspected human carcinogen. The ECHA has recommended that workers be protected from inhaling titanium dioxide dust and that the substance is labeled as a carcinogen when used in certain industrial processes. The ECHA has also recommended that titanium dioxide be used in a form that is less likely to be inhaled, such as in the form of a paste or a solution, rather than in a dry powder form.

It is important to note that the ECHA's classification of titanium dioxide as a suspected human carcinogen is based on studies of workers who were exposed to high levels of titanium dioxide dust over long periods. The potential health effects of lower levels of exposure, such as those that might occur when using products that contain titanium dioxide, are not fully understood

Overall, the debate over the use of TiO2 is ongoing, and additional restrictions or bans will likely be implemented in the coming years as more information becomes available about the potential risks and benefits of TiO2.

CONCLUSION

Overall, the use of TiO2 nanoparticles has the potential to bring many benefits, but there are also concerns about their potential environmental and health impacts. Further research is needed to understand the full range of risks and benefits associated with the use of TiO2 nanoparticles.

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