Titanium Dioxide

A brief overview - Toxic or Safe?

There has been some concern over the use of titanium dioxide in cosmetics. Titanium dioxide is regarded as an inert, non-toxic substance by many regulatory bodies and it serves several purposes in cosmetics. It is a white pigment, an opacifier and a sunscreen.

However, certain studies have pointed to titanium dioxide as a carcinogen and photocatalyst, thus creating fear in consumers. But are these claims true? What does the research on these allegations bear out? Would we as consumers benefit from avoiding this mineral to preserve our long-term health?

What the Studies Show

Studies Relating to Topical Application

Titanium Dioxide and Hydroxyl Free Radicals (Research)

- Dunford, R., et al. Chemical oxidation and DNA damage catalysed by inorganic sunscreen ingredients. FEBS Lett. 418(1-2):87-90, 1997.

Topically-applied micronized titanium dioxide was found to cause DNA damage in skin cells.

Titanium dioxide (TiO_2) has been noted (US Federal Register, 43FR38206, 25 August 1978) to be a safe physical sunscreen because it reflects and scatters UVB and UVA in sunlight. However, TiO_2 absorbs about 70% of incident UV, and in aqueous environments this leads to the generation of hydroxyl radicals which can initiate oxidation. Using chemical methods, the authors show that all sunscreen titanium dioxide samples tested catalyze the photo-oxidation of a representative organic substrate (phenol). They also show that sunlight-illuminated titanium dioxide catalyzes DNA damage both in vitro and in human cells. These results may be relevant to the overall effects of sunscreens.

Titanium Dioxide vs. Other Sunscreen Ingredients

Microfine Zinc Oxide is superior to (Microfine) Titanium Dioxide (when used as a Sunscreen). It is more protective against Ultra-Violet Radiation and possesses a less-white physical appearance on the Skin. Zinc Oxide does not generate Free Radicals in the Skin when it is exposed to Ultra-Violet Radiation (which Titanium Dioxide DOES). Zinc Oxide does not cause (Skin) Allergies (neither does Titanium Dioxide).

Peer-Reviewed Professional Journals

- Pinnell, S. R., et al. Microfine zinc oxide is a superior sunscreen ingredient to microfine titanium dioxide. Dermatol Surg. 26(4):309-314, 2000

Microfine zinc oxide and microfine titanium dioxide are particulate sunscreen ingredients that absorb broad-spectrum ultraviolet (UV) irradiation. The authors compared microfine zinc oxide and microfine titanium dioxide for their abilities to attenuate UVA radiation and their relative whiteness in cosmetic formulations. UVA attenuation was measured by diffuse reflectance spectroscopy on normal human skin in vivo. Whiteness was determined by reflectance density of dried coatings on a black background of the two particulates at varying concentrations. Microfine zinc oxide demonstrates superior protection compared to microfine titanium dioxide in the UV spectrum between 340 and 380 nm. Microfine zinc oxide is less white than titanium dioxide at all concentrations. Microfine zinc oxide is superior to microfine titanium dioxide as a sunscreen ingredient. It is more protective against long-wave UVA and is less white at a given concentration.

Studies Relating to Inhalation

There was also a study by Lee, Trochimowicz & Reinhardt, "Pulmonary Response of Rats Exposed to Titanium Dioxide by Inhalation for Two Years" (1985). The authors of this study found that rats chronically exposed to excessive dust loading of 250 mg/m cubed and impaired clearance mechanisms within the rat, for six hours per day, five days per week for two years, developed slight lung tumours.

Evidence showed that high concentrations of pigment-grade (powdered) and ultrafine titanium dioxide dust caused respiratory tract cancer in rats exposed by inhalation and intratracheal instillation*. The series of biological events or steps that produce the rat lung cancers (e.g. particle deposition, impaired lung clearance, cell injury, fibrosis, mutations and ultimately cancer) have also been seen in people working in dusty environments. Therefore, the observations of cancer in animals were considered, by IARC, as relevant to people doing jobs with exposures to titanium dioxide dust. For example, titanium dioxide production workers may be exposed to high dust concentrations during packing, milling, site cleaning and maintenance, if there are insufficient dust control measures in place. However, it should be noted that the human studies conducted so far do not suggest an association between occupational exposure to titanium dioxide and an increased risk for cancer.

What This Means for Us

You will notice that the above studies regarding the topical application of titanium dioxide involve the micronized / microfine form. The one form of mineral or mineral extract, including titanium dioxide, that we **should** be concerned about are these ultrafine or nano particles. As technology has advanced, so has its ability to take normal sized particles of minerals and reduce them to sizes never before imagined. While many are praising this new technology, others are warning of its inherent dangers to our bodies. A study by Churg et. al. at the University of British Columbia in their paper "Induction of Fibrogenic Mediators by Fine and Ultrafine Titanium Dioxide in Rat Tracheal Explants" (1999) found that ultrafine particles of the anatase form of titanium dioxide, which are less than 0.1 microns, are pathogenic or disease causing.

▪ **Measurements of Mineral Pigment Particles**

Particle Size	*Measurement*
Coarse	Less than 10 microns
Fine	Less than 2.5 microns
Ultrafine (nanoparticles)	Less than 0.1 microns or 100 nanometres

▪ **Particle Size and Entry into the Human Body**

Nanoparticle Size	*Entry Point*
70 nanometres	Alveolar surface of lung
50 nanometres	Cells
30 nanometres	Central Nervous System
Less than 20 nanometres	No data yet

From the above tables it is evident that *the smaller the particle size, the more toxic it is*. Nanoparticles of titanium dioxide are used in sunscreens because they are colourless at that size and still absorb ultraviolet light. Many cosmetic companies are capitalizing on metal oxide nanoparticles. We have seen, however, that if titanium dioxide particles used to act as a sunscreen are small enough, they can penetrate the cells, leading to photocatalysis within the cell, causing DNA damage after exposure to sunlight (Powell, et. al. 1996) The fear is that this could lead to cancer in the skin. Studies with subjects who applied sunscreens with micronized titanium dioxide daily for 2-4 weeks showed that the skin can absorb microfine particles. These particles were seen in the percutaneous layers of the skin under UV light.

The above study relating to inhalation of titanium dioxide noted that the biological relevance of this data to lung tumours in humans is negligible. It is important to note that rats are known to be an extremely sensitive species for developing tumours in the lungs when overloaded with poorly soluble, low toxicity dust particles. Rat lungs process particles very differently compared to larger mammals such as dogs, primates or humans (Warheit, 2004). This sensitivity in the lungs has not been observed in other rodent species such as mice or hamsters (Warheit, 2004), therefore using the rat model to determine carcinogenicity of titanium dioxide in humans can be misleading, as extrapolation of species-specific data to humans is erroneous.

Several studies and study reviews have been used to compile the safety disclaimers for the regulations on the permitted use of titanium dioxide. One such study review took place in Rome, 1969 between the World

Health Organization and the Food & Agriculture Organization of the United Nations. Cross species analyses were performed and reviewed for possible toxicity of titanium dioxide. The conference concluded that among the following species: rats, dogs, guinea pigs, rabbits, cats and human males, ingestion of titanium dioxide at varying diet percentages and over long periods of time did not cause absorption of this mineral. Titanium dioxide particulates were not detected in the blood, liver, kidney or urine and no adverse effects were noted from its ingestion. The U.S. Food & Drug Administration (2002) allows for its ingestion, external application including the eye area, and considers it a safe substance for public health.

Other epidemiological studies showed that workers exposed to titanium dioxide showed no statistically significant relationship between such exposure with lung cancer and respiratory disease, although some cases of pulmonary fibrosis did occur. These studies were conducted in *industrial* settings where the *increased exposure* puts these individuals more at risk than the average person.

Titanium dioxide is listed as a safe pigment, with no known adverse effects. It is not listed as a carcinogen, mutagen, teratogen, comedogen, toxin or as a trigger for contact dermatitis in any other safety regulatory publications beside the NIOSH (Antczak, 2001; Physical & Theoretical Chemical Laboratory, Oxford University respectively). It is reasonable to conclude then, that titanium dioxide is not a cancer-causing substance and is generally safe for use in foods, drugs, paints and cosmetics.

Weighing Up the Evidence

As with any health issue, relevant studies must be examined closely to reach balanced conclusions about its impact on our health and well-being. Often, risk determinations are made without considering actual hazards and real-life exposures (Warheit, 2004).

For example it seems obvious to me that any particles that are inhaled for a significant number of hours and over a long period of time might cause the body a problem. Also, several factors influence the effects of inhaled particles. Among these are some properties of the particles themselves. Size and heaviness are important because large and heavy particles settle more rapidly. Chemical composition is important because some substances, when in particle form, can destroy the cilia that the lungs use for the removal of particles. Cigarette smoking may alter the ability of the lungs to clear themselves.

Characteristics of the person inhaling particles can also influence the effects of dust. Breathing rates and smoking are among the most important. The settling of dust in the lungs increases with the length of time the breath is held and how deeply the breath is taken. Whether breathing is through the nose or mouth is also important.

The classic diseases of "dusty" occupations may be on the decline, but they have not yet disappeared. Workers today still suffer from a variety of illnesses caused by dust they inhale in their work environments. Some types of lung diseases caused by the inhalation of dust are called by the general term "pneumoconiosis." This simply means "dusty lung."

Conclusion

According to the studies available and information discussed in this article it appears that coarse or fine particles of titanium dioxide are safe to use and when applied topically as a component of some sunscreens, protects the skin against the toxic effects of the UV-A and UV-B spectrums of ultra-violet radiation.

However, consumers should *avoid* using products with *micronized* mineral pigments, either in sunscreens or colour cosmetics. When you are applying mineral cosmetics, if you want to avoid inhalation, hold your breath!

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