How does the nanotechnology science in sunscreens affect our lives?

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ABSTRACT

Throughout this paper I intend to analyse the structure of sunscreens and how the nanotechnology science involved in them works. I will be carrying out a gedankenexperiment – this translates to 'thought experiment' from German. I will carry out my research using papers already published and websites that contain relevant information to this topic. As my title suggests, I will be looking into how the nanotechnology in sunscreens affects our lives: so as well as learning about the nanotechnology, this paper will also consider the social and health problems relating to sunscreens.

INTRODUCTION

I have had a keen interest in the protection of the human body against dangers presented in everyday life since an early age. I chose to research into sunscreen nanotechnology as the extremely small scale by which sunscreens work immediately fascinated me, as it involves using something very tiny to impact on the effects of something that is very large (i.e. the sun). By carrying out research I hope to understand the way in which nanotechnology is involved in sunscreens and also how sunscreens prevent irreversible damage caused by ultraviolet rays which beam down from the sun.

Nanotechnology

Nanotechnology is the study of the manipulation of atoms and molecules to form structures on a Nano scale (one Nano metre = one billionth of a metre (10^{-9}m)). Once these new structures are developed, new properties that can be observed in the materials (including: chemical, biological and physical properties) that are different to any macromolecules they may be constituents in; this is due to the quantum science they are newly subjected to.

The development of Nanotechnology

The potential of Nanotechnology was first recognised by physicist Richard Feynman at a lecture given on the 29th December 1959 at an American Physical Society meeting. He stated that it might be possible to fabricate materials on an atomic and molecular scale to develop new properties. He noted, that due to the miniature size of these new materials, physical spectacles largely influential in the current macromolecules would prove less applicable in some cases and more so in others: surface tension, surface area and the Van Der Walls forces of attraction would be much more significant, whereas gravity, for example, would be less significant.

Nanotechnology in medicine

Nanotechnology makes multiple appearances in modern medicine and I believe it will continue to do so for many centuries, if not millennia. Nanotechnology is used in drug delivery, it gives various possibilities for fighting against cancer, and even Nano sized cell repair machines have been developed. The nanometre scale all these applications are based upon is extremely useful in medicine, as it allows a person being treated to not suffer from the discomfort they may feel if a similar but larger method was used. An example of this is seen in the bioavailability that Nano engineered drugs can achieve. They can provide a longer and more effective delivery of a drug to the areas that need it the most. This avoids the laborious task of taking drugs repetitively and the drugs can be taken less often as it has a longer lasting effect. Another example is the ability to coat orally administered drugs with a film of nanoparticles so they are not broken

down in the acidic conditions the stomach presents. This avoids having to inject a drug, negating the need for needles (of which some people have phobias) and saving money too.

However, my main focus is on sunscreens and the nanotechnology found in them. They provide maximised protection from the harmful Ultraviolet rays beaming down from the sun, all down to the intellectual design of the sunscreens on a molecular scale.

Ultraviolet Radiation

Ultraviolet radiation is a wavelength found in the electromagnetic spectrum, which has a shorter wavelength than the common visible light. It is named 'Ultraviolet' due to being of a wavelength just shorter than that which humans see as violet in colour (Ultra meaning beyond). As it is beyond the violet colour, and beyond the human visible scale, it is invisible. However, people can still recognise its effects as it causes a painful burn after over exposure and also causes many other health problems.

The sun is the most universally known source of natural Ultraviolet radiation (some extremely hot stars are known to emit more) and emits it in three bands: UVA, UVB and UVC. The Earth's Ozone blocks out approximately 97-99% of the Ultraviolet radiation emitted from the sun. A large majority of the radiation that passes through and reaches the earth's surface is UVA (but the other two still reach us too). The table on the right describes the effect each band of Ultraviolet radiation has on the body.

Effects of UV Rays	
UVA	Causes the pigments in our skin to tan. However, these rays also lead to skin ageing and other adverse effects which is why exposure shoud always be limited.
UVB	Causes DNA damage (increasing Melanin production) and is the main cause of sun burn, peeling and eventually non-melanoma skin cancer.
UVC	Is the most harmful UV ray and is predominantly filtered out by the ozone layer (which is fortunate as even short exposure is extremely harmful to the eyes and skin).

Figure 1

The earth relies on the sun to provide the light for life to survive; without it we would be non-existent. It also facilitates creation of vitamin D from which many organisms benefit. But over exposure to the sun can lead to many diseases and problems due to the harm caused by UV rays in large quantities.

It is widely known that exposure to the sun can give a fashion led 'suntan', but it is the skin surrounding your bones that you need to think about before lying unprotected below a sky of harmful Ultraviolet rays (UV Rays). Scientists have labelled UV rays as very harmful; they can cause the skin to become painful after being burnt, and in the long run and most importantly: cancerous mutations can occur which is obviously life threatening.

History of Sunscreens

Scientists are however trying their best to protect the people of planet Earth from the severities posed by over exposure to UV rays emitted from the sun. The first effective sunscreen is said to have been composed in 1938. Later, in 1944, a cream was developed to act as a physical blocker to stop the UV rays reaching the skin. It was developed during World War II as soldiers became aware of the hazards presented in the hotter climates they were adventuring to, to protect their country. The first sunscreen to go on sale did so in the 1960s, and it too aimed to protect the skin from Ultraviolet radiation. And finally in the 1990s, zinc and titanium oxide were introduced to sunscreens to add another level of protection – this was the introduction of nanotechnology.

Nanotechnology Introduction to sunscreens

Nanotechnology is an extremely beneficial development for sunscreens. It allows atoms and molecules to protect skin from harmful UV rays that are a few hundred nanometres wide ('like' is protecting against 'like'). Nanotechnology in sunscreens allows deeper penetration into the skin, providing much more protection than if an unsightly, thick, greasy layer was to be built upon the skin surface to protect from the ultraviolet radiation. Scientists have further developed the nanotechnology of sunscreens to allow them to sit on the skin surface, and even slightly penetrate the epidermis to increase protection against the harm presented by ultraviolet radiation.

DISCUSSION

The development of Nanotechnology

Nanotechnology, being a relatively new discovery, is still advancing in its development for use in numerous applications. The nanometre scale achieved allows new materials, products and structures to involve nanotechnology giving it new properties; phenomena such as surface tension, surface area and the Van Der Waals forces are much more significant with respect to the molecular size.

What are scientists doing and why?

Scientist discovered that UV rays caused harm to the human race many decades ago, and have been developing sunscreens to help to protect our bodies since this discovery. It is a valid assumption that any sunscreen on the modern market contains nanoparticles to prevent sunburn and to attempt to reflect the rays away. The idea of using nanotechnology to protect the skin has been undoubtedly developed since its early introduction into sunscreens. No longer is the white mask of cream seen, and neither is having molecules sit on the skin in a bid to avoid exposure. The latest development has been to have nanoparticles penetrate the skin, not deep enough to cause harm but far enough below the surface to provide increased protection. This allows the body to be covered by a thin film of nanoparticles, providing protection more discreetly than when it was first discovered and developed.
Scientists continue to research into nanotechnology as products can always be improved to make them feel better, look nicer, easier to use or more cost effective. This has most definitely been the case with sunscreen development.

What is the nanotechnology held within sunscreens?

Most sunscreens available to the consumer today are likely to contain nanoparticles of Zinc oxide and/or titanium dioxide. Their selection from a long list of molecules, having looked at the table on the right, is self-explanatory: they provide the most extensive protection from UV radiation. In pre-nanotechnology sunscreens the zinc oxide and titanium dioxide molecules sat on the skin surface, as they were not absorbed. This is an advantage in sunscreens as it ensures these particles do not react of cause irritation to the consumer when applied (they are both non-irritating and non-allergenic). However, by not being absorbed, a white colour was given to the skin as the titanium and zinc could not be absorbed into the skin and collected on the skin. The nanoparticle forms of zinc oxide and titanium dioxide are known to be absorbed by the skin, leaving no white colour behind, but it is unsure as of yet if any health problems are caused by their absorption. Zinc Oxide is used in sunscreens because it blocks both UVA and UVB considerably more effectively by scattering the rays, giving a broad protecting from harmful radiation.

FDA Monograph Sunscreen Ingredients	Amount of Ray Protection		Chemical (C) or Physical (P)
	UVA	UVB	
Aminobenzoic acid (PABA)	○	●	C
Avobenzone	●	◴	C
Cinoxate	◴	●	C
Dioxybenzone	◐	●	C
Ecamsule	●	◴	C
Homosalate	○	●	C
Menthyl anthranilate	◐	●	C
Octocrylene	◴	●	C
Octyl methoxycinnamate	◴	●	C
Octyl salicylate	○	●	C
Oxybenzone	◐	●	C
Padimate O	○	●	C
Phenylbenzimidazole	○	●	C
Sulisobenzone	◐	●	C
Titanium dioxide	◐	●	P
Trolamine salicylate	○	●	C
Zinc Oxide	●	●	P

Protection Level: ● = extensive ◐ = considerable ◴ = limited ○ = minimal

Figure 2

Titanium Dioxide is a constituent in most physically blocking sunscreens due to its high refractive index rating, resistance to decolourisation during exposure and also for its Ultraviolet absorption capabilities. One problem posed is that untreated titanium dioxide molecules can create radicals (a very reactive species that are carcinogenic). To tackle this problem the molecules are coated with silica or alumina to prevent radical formations.

The need for sunscreens

To venture outside on a hot sunny day without the trusted sunscreen applied, is in my opinion extremely irresponsible as you are exposing your skin and cells to damaging conditions. Many diseases and medical health problems are linked with over exposure to the Sun's harmful UV rays, but ironically, problems can occur from under exposure too!

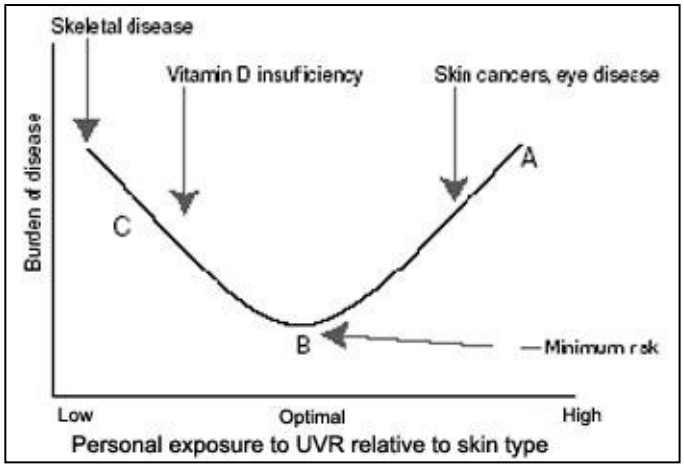

Figure 3

The graph on the left shows the 'Burden of Disease' against 'personal exposure' to UV radiation. It can be seen that minimal risk is presented at an optimal exposure. Some Ultraviolet exposure is beneficial to the body as this is the mechanism by which we generate Vitamin D production. Direct sunlight exposure initiates the natural process of Vitamin D (a group of fat soluble substances) production. It is an essential vitamin as it helps to prevent us from developing several chronic diseases, including: diabetes, heart disease, hypertension, osteoporosis, breast cancer, colon cancer and ovarian cancer.

So is it best to stay unprotected in the sun to ensure we gain enough direct sunlight to produce sufficient amounts of vitamin D to reduce the occurrence of these chronic diseases? The answer is no! Protection is essential when the sun is bright and hot, because there is also another long list of diseases linked to over exposure of the sun. The most notorious of these diseases is unfortunately skin cancers. There are three main types of skin cancer:

I. **Malignant Melanoma –** it begins in moles and spreads throughout the body and kills you. It needs to be treated very early otherwise fatal consequences are faced.
II. **Squamous Cell Cancer –** can become fatal if it spreads throughout the body.
III. **Basal Cell Skin Cancer –** most common of the three but rarely spreads through the body. This cancer can only be cured by 100% removal of the lesion – as cancers continuously grow and removal is the only action that can cure the patient.

All three of these cancers can cause death of the person hosting their growth, but all can similarly be treated. But the proactive approach of protecting the skin from the sun that sunscreens provide us is much more beneficial than treating cancerous cells. By having cancer you would be affected both physically and emotionally. The key is to prevent cancerous developments rather than allow them to occur and then treat them.

Over exposure to the sun can cause multiple diseases and health problems other than cancers:

- Sunburn

- Benign Tumours
- Sun induced freckles
- Wrinkles
- Discoloured areas of skin
- Yellow discolouration of the skin
- Dilation of the small blood vessels found under the skin
- Reactivation of Herpes – over exposure to the UV radiation from the sun can cause the immune system to weaken and the reactivation of Herpes Virus (cold sores) on the lips

It is evident from the long list of related health problems above that some protection should be worn when the hot sun is in sight. But it is also to be noted that we need some Ultraviolet radiation to prevent many chronic diseases caused by Vitamin D deficiency. The balance must now be achieved: enough sunlight to avoid chronic diseases, with enough protection to ensure we are safe from cancerous developments and other health risks posed by over exposure. An optimum exposure – as the graph on page 6 shows – is what each person should aim to achieve, to guarantee a much-reduced chance of suffering from Sun related ailments.

Social and Practical Factors

With the health side considered, I will take a look at social factors that affect how willing people are to wearing a sunscreen and protecting their bodies from the harmful UV radiation that reaches the Earth's surface. There are four areas I propose looking into for the social aspects: how it looks, how it feels, how easy it is to use and how much it costs.

Looking good

If you buy a product from a shop, you'd expect it to satisfy your needs and sunscreen does just that. But in early development the titanium dioxide molecules proved an unsightly problem when they left a white colour on the skin. Complaints were made about this 'side effect' and manufacturers looked into producing a less visible sunscreen, and nanotechnology provided an answer. A sunscreen that left no white colour behind after being applied was developed, a person's image would not be affected by a white masking of the skin, with no alteration to the protection rating of the sunscreens being used. Traditional forms of Zinc Oxide (ZnO) and Titanium Dioxide (TiO_2) had been substituted for their nanoparticle equivalents. Figure 4 displays an image of the white colour left on the skin after application of traditional sunscreens. In contrast, the top left of this image demonstrates the application of a nanoparticle sunscreen, which leaves no residue on the skin.

Figure 4

Feeling Comfortable

Nanotechnology has attempted to make sunscreens much more comfortable on the skin. The traditional molecules were too large to soak through the skin, and so they sat upon the surface. This did ensure that a layer of molecules could reflect rays and protect the skin, but an

unpleasant feeling was a common complaint as people had a conscious awareness of the greasy look they wore. By developing nanoparticle substances for sunscreens, this greasy look could be sunk out of sight and into the epidermis of the skin. This gives a less intrusive design and more people would be willing to apply sunscreen, as it was both invisible to the eye when worn and it felt comfortable too, as clothing and furniture would not stick to it.

Ease of Use

All sunscreen manufacturers know that it is a fundamental point of production that their product must be easy to use. Otherwise, their customers will neglect their produce and look for a much more effective and easy to use brand. Nanotechnology in sunscreens allows the applied cream to easily soak through the skin epidermis and not be seen. This was a major development in comparison to when pre-nanoparticle sunscreens where manufactured. In their early years, the particles sat upon the skin, leaving a thick, white and lumpy feel and look to the sunscreen. Unfortunately, it had to be reapplied frequently as these sunscreens were not as protective. Advances in nanotechnology science allowed these problematic features to be addressed and abolished. The nanoparticles were developed and allowed the sunscreen to be spread over the skin with ease, making application easier and coverage of the whole skin more likely.

Cost of the Product

Product prices, a thing everyone worries about. Sunscreens have to be affordable or they won't be worn. Nanotechnology provides an increased protection compared to other sunscreens that only contain natural minerals for Ultraviolet filtration. Because of this, many nanoparticle containing sunscreens are mass-produced, thus reducing its shelf price. New regulations concerning SPF ratings (Sun Protection Factor) are resulting in fewer natural sunscreens being sold, as they are not capable of providing such protection.

Future Developments

Sunscreens are continually redeveloped to satisfy the changing needs of the customer. Future developments of nanotechnology will of course benefit sunscreen manufacture extensively. New nanoparticles could be introduced to penetrate deeper and provide extended protection without frequent reapplication. Formulations could be introduced that are more sweat and water resistant, this would be a very practical development for sports persons as less consideration would have to be given to reapplying the sunscreen during exercise. Another development would be the continuation of striving towards a less greasy feeling; this would work towards an unaffected grip on objects.

The above all satisfy practical factors. A feature that sunscreens could develop is the protection against the whole UV spectrum. As of current, most sunscreens protect against UVB but do not provide good protection against UVA. This protection could be increased and UVC protection could also be developed.

CONCLUSION

My thoughts

In answer to my paper title (How does the nanotechnology science in sunscreens affect our lives?), I think that nanotechnology has been essential in improving the proactive approach to preventing many diseases. It has also complied to social factors that if not answered may have led to fewer people wearing protection. Modern sunscreens: look good when worn, feel comfortable on the skin, are relatively inexpensive and are easy to apply without frequent reapplication required.

How does sunscreen affect our lives? It is extensively proven to reduce the risk of life threatening diseases, thus it plays a major part in every bodies' lives. The only other alternatives to staying protected are impractical: either stay indoors all the time, or only adventure outside clothed from head to toe to prevent exposure.

Nanotechnology has most definitely been beneficial to sunscreen development as it has given: an extended period of protection, answers to practical problems posed by pre-nanoparticle sunscreens and if used correctly, give a reduced risk of a large list of chronic diseases related to over exposure to UV radiation. However, I believe more research must be committed to understanding how the nanoparticles act below the skin after penetrating the epidermis. It is currently unknown how far they penetrate, is it invasive on living cells? Can they reach as far as the blood stream? Once these questions can be answered, there will no longer be scepticism about whether the nanoparticles are preventing as many diseases as they may be causing.

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