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To the State Secretary for Youth, Prevention and Sport and the Inspector General of the Netherlands Food and Consumer Product Safety Authority

Advice from the Director of the Office for Risk Assessment and Research

Regarding the health risks of insufficient UV protection in sunscreen products

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Background

Ultraviolet (UV) radiation from the sun can cause skin cancer, the most common type of cancer in the Netherlands. According to KWF (the Dutch Cancer Society), every year more than 70,000 new patients are diagnosed with skin cancer. Sunscreen products are used to protect the skin against UV radiation. The Sun Protection Factor (SPF) is the means by which manufacturers of these products indicate the level of protection the product offers against UV radiation. The higher the factor, the greater the protection.

In 2023, the Enforcement directorate of the Netherlands Food and Consumer Product Safety Authority (NVWA) conducted a study of the UV protection of sunscreen products on the Dutch market. The NVWA sampled a number of sunscreen products with a claimed SPF of 30 and 50. The NVWA laboratory subsequently determined the SPF of these products using an *in vitro* method, in which sunscreen products were applied to test plates in order to measure the transmission of UV radiation. If the test reveals that a sunscreen product does not reach the claimed SPF, the NVWA can impose a measure. To substantiate any measures, the Enforcement directorate posed the following question to the Office for Risk Assessment and Research (BuRO) of the NVWA:

At what deviation from the SPF measured using in vitro *methods as compared with the SPF claimed on the product does a (serious) health risk occur?*

To be able to answer this question, BuRO added the following questions:

What are the risks to the consumer from the harmful effects of UV radiation based on the available product information regarding sunscreen products?
- *How is the system of classification/categorisation of sunscreen products structured?*
- *What methods are available for determining the SPF, and what are their advantages and disadvantages?*

Approach

To obtain the necessary information to thorough and accurate answers to the research questions, the first aspect considered was the harmful effects of UV radiation. The study then focused on the nature of sunscreen products, the legal requirements imposed on such products, and the test methods available for measuring the UV protection that they offer. Consideration was also given to other factors which have an impact on the UV protection provided by sunscreen products. Finally, the approach examined the potential health risks of products with an SPF that was lower than claimed by the manufacturer.

Questions were submitted to the RIVM WFSR Front Office Food and Product Safety regarding the health risks of sunscreen products with an SPF lower than the

claimed SPF. Moreover, BuRO conducted a literature study (see Annex 1). The data from the NVWA laboratory study of sunscreen products were used for the exposure assessment.

BuRO conducted the risk assessment of sunscreen products in accordance with the four steps of risk assessment described in the BuRO method for physical hazards: hazard identification, hazard characterisation, exposure assessment and risk characterisation. The effect of sunscreen products and the methods for measuring SPF also formed part of the assessment.

This advisory report is restricted to the health risks arising from UV radiation that originates from the sun and the protective effect of sunscreen products. Sunbeds as a source of UV radiation are not considered. The health risks of chemical and other substances in sunscreen products are also beyond the scope of this risk assessment, as is the impact of sunscreen filters on the environment. The content of this report has been externally peer reviewed.

Findings

Hazard identification

UV radiation from the sun that reaches the surface of the Earth is divided into three types on the basis of wavelength: UVA (315-400 nm), UVB (280-315 nm) and UVC (100-280 nm). The ozone layer prevents the passage of 100% of UVC radiation and the majority of UVB radiation. At sea level, UV radiation from the sun consists of 95% UVA and 5% UVB.

Hazard characterisation

Both UVA and UVB radiation can cause skin damage, with UVA radiation penetrating more deeply into the skin than UVB radiation, but with less energy. A positive effect of UVB radiation is the production of vitamin D by the skin following exposure. The negative effects of UV radiation are erythema, skin cancer and skin ageing. Erythema is the reddening of the skin (sunburn) due to an inflammatory reaction, which is primarily caused by UVB radiation. Premature skin ageing due to loss of collagen is caused by UVA radiation. Skin cancer can be caused by both UVA and UVB radiation, and is an effect without threshold. The most commonly occurring forms of skin cancer are basal cell carcinoma (often easily treated), squamous cell carcinoma (which can metastasise but generally remains localised) and melanoma (the most aggressive form of skin cancer). In the present assessment, BuRO views skin cancer as the critical effect of exposure of the skin to UV radiation. Biological amplification factors have been derived for the occurrence of the three most common types of skin cancer. These values indicate the percentage by which the incidence of each type of skin cancer will alter as the dose of UV radiation rises by 1%. The biological amplification factor for basal cell carcinoma has a value of 1.4, for squamous cell carcinoma 2.5 and for melanoma 0.6.

Legislation

- Sunscreen products are cosmetic products and must comply with the Cosmetics Regulation (EC) No. 1223/2009. According to this Regulation, cosmetic products must be safe for public health under normal or reasonably foreseeable conditions of use. Recommendation 2006/647/EC contains requirements and test methods for sunscreen products. SPF refers to the ratio between the minimum erythemal dose on skin protected by a sunscreen product and the minimum erythemal dose on the same skin without protection. Because erythema is related to UVB, SPF is related to UVB protection. This Recommendation also specifies that sunscreen products must offer protection against UVA radiation, equivalent to at least one third of the UVB protection. The European Working Group on Cosmetic Products and Sub-group on

Sunscreens is currently working on an update to this Recommendation. The Claims Regulation (EU) No. 655/2013 stipulates that claims on cosmetic products must be substantiated. Proof that the sunscreen product has the claimed SPF must be included in the product information file.

- There are different ways to measure the SPF of sunscreen products: *in vivo, in vitro,* in silico and a hybrid form (see Table 5 in the substantiation). Recommendation 2006/647/EC specifies *in vivo* methods as reference methods for determining protection against UVA and UVB radiation. ISO 24444 is the reference method for UVB protection, which is assessed by measuring the erythemal response. The reference method for *in vivo* UVA protection is ISO 24442, based on 'persistent pigment darkening'; the discoloration (tanning) of the skin. The Recommendation states that *in vitro* tests are preferable provided that they deliver comparable results, because the *in vivo* method raises ethical objections. Working group ISO/TC217/WG7 has developed two ISO standards (ISO/DIS 23675 and ISO/DIS 23698) for *in vitro* measurements of UVA and UVB protection offered by sunscreen products. A draft ISO standard of both methods has now been published.
- BuRO has expressed a number of reservations about the different test methods:
    - Both *in vivo* reference methods use an acute effect of UV radiation on the skin (reddening and tanning) as a measurement for UV protection. However, it remains unclear whether protection against this acute effect is also a reliable measurement for protection against skin cancer in the long term. From an ethical viewpoint, too, it is undesirable to expose test subjects to harmful UV radiation. The *in vivo* reference methods are used on test subjects with a single specific skin type. It is unknown how representative this is for other skin types.
    - In the *in vitro* methods currently most widely used, correction factors are applied to the measured values in order to correlate the results with those from the *in vivo* reference methods. Furthermore, at present there is no effective way to simulate the properties of human skin.
    - For both *in vivo* and *in vitro* methods, the prescribed quantity applied is higher than the quantity consumers apply in reality. As a consequence, the SPF measured will be higher than the actual UV protection that the consumer receives from everyday use.

Exposure assessment

- Little is known about the extent to which people in the Netherlands are exposed to sunlight. The power of the sun and the related exposure to UV radiation are highest in the spring and summer between 12 pm and 3 pm. Exposure to UV radiation from the sun has probably risen over the past few decades due an increase in the number of hot days in combination with an increase in the amount of leisure time people spend outdoors. Moreover, the level of UV radiation in the Netherlands has risen over the past decades.
- The NVWA measured the UVA and UVB protection offered by 54 sunscreen products with a claimed SPF of 30 or higher, using an *in vitro* method known as the double plate method. The full results can be found in Annex 2. Thirty-six sunscreen products (67%) had a lower SPF than claimed, and for 8 sunscreen products (15%), the measured SPF was lower than 10. Forty-eight sunscreen products (89%) offered a level of UVA protection equivalent to at least one third of the UVB protection.
- In 15 sunscreen products (28%), a reduction of more than 20% in the SPF measured was observed using the *in vitro* method, following irradiation with UV light. The UV filters in these sunscreen products are not stable and as a result they offer protection for a shorter period than consumers may assume.
- Moreover, an external laboratory measured the SPF of 13 sunscreen products using ISO 24444 (*in vivo* reference method). Another external laboratory

analytically determined the levels of UV filters, which enabled the SPF of the sunscreen product to be calculated using the in silico method. These three different test methods resulted in a wide divergence in the SPF offered by the sunscreen products. In most cases, the *in vivo* reference method resulted in higher SPF values as compared with the SPF determined using the *in vitro* or in silico method but in these tests too, 8 of the 13 samples examined (62%) were shown to have a lower SPF than claimed.

- The results of the NVWA study do not offer sufficient basis for a quantitative exposure assessment due to the reservations about the methods used.
- The NVWA study and the literature study reveal that the following factors impact on the eventual exposure to UV radiation and the protection offered by the sunscreen product:
  - The anti-inflammatory effect of substances in sunscreen products, which suppress the erythemal response and lead to higher SPF measurements *in vivo*. Erythema is a warning sign for consumers regarding the harmful effects of UV radiation.
  - The stability of UV filters, resulting in a decline in the level of protection following exposure to sunlight which means that the claimed protection is not sustained for the entire period of use (2 hours).
  - How consumers use the product, usually applying only a half to a quarter of the recommended quantity of 2 mg/cm^2.
  - The difference in skin types. The *in vivo* tests are carried out on a single specific skin type, which is not representative for other skin types.
  - Sensitivity to UV radiation. Children, people with pale skin and people with a weakened immune system are more sensitive to skin damage caused by UV radiation and have a greater need for sunscreen products or clothing to protect them from the harmful effects of the sun.

Risk characterisation

- Given that no quantitative exposure assessment is possible, a quantitative risk characterisation cannot be conducted.
- Exposure of the skin to UV radiation depends not only on the protection offered by the sunscreen products but also the skin type, consumer use and the intensity of the sun's rays at a given time.
  If a sunscreen product offers less protection than the consumer assumes on the basis of the claimed SPF, the consumer will be exposed to more UV radiation than expected, thereby increasing their risk of developing skin cancer.

Uncertainties

- The two *in vivo* reference methods are based on an observable acute effect. It is unclear to what extent this effect correlates to protection against long-term effects, premature skin ageing and skin cancer.
- The *in vitro* method used involves a step whereby the sunscreen product is applied to plates which are then irradiated with UV light to test the stability of the UV filters. The dose of UV light depends on the SPF measured prior to irradiation. Certain sunscreen products are irradiated for more than 4 hours, while the consumer is advised to reapply sunscreen every 2 hours. This results in over irradiation during the *in vitro* method, and so the SPF measured may be lower due to the breakdown of the UV filters than it would be after 2 hours of irradiation.
- The quantity of the product that consumers apply is less than the quantity used in both the *in vivo* and the *in vitro* method. There is no exact data on the quantity of the product that Dutch consumers apply and whether they reapply every 2 hours as recommended. The UV protection measured on the basis of the quantity used in the tests is therefore an overestimation of the actual UV protection experienced by consumers.

Conclusions

- To protect the skin against the occurrence of skin cancer, it is important that sunscreen products offer protection against both UVA and UVB radiation.
- Given the reservations expressed about both the *in vitro* and *in vivo* method, no conclusion can be reached regarding the actual UV protection of the tested sunscreen products. The *in vitro* method is currently corrected on the basis of results obtained using the *in vivo* reference method. However, the *in vivo* reference method is not based on the critical effect (occurrence of skin cancer). Nor is it clear to what extent the measured effect (erythema) correlates to UV protection. There are also other factors that affect the actual UV protection of a sunscreen product, such as the stability of the UV filters, skin type and how consumers apply the product.
- In a number of cases, the methods employed result in a significant difference in SPF, with the *in vitro* method delivering lower values than the *in vivo* method. The presence of anti-inflammatories in the sunscreen product may account for this difference, resulting in a higher SPF when measured *in vivo* than *in vitro*. However, these anti-inflammatory substances have not been analytically investigated as part of the NVWA study.
- Using a sunscreen product with an actual SPF that is lower than the claimed SPF leaves the consumer more exposed to UV radiation. In the short term, any additional exposure to UV radiation can lead to more frequent occurrence of erythema. In the long term, higher exposure will increase the risk of skin cancer.

Answering the questions

When the SPF measured using in vitro *methods deviates from the SPF claimed on the product, at what point does a (serious) health risk occur?*

An increased health risk occurs if the actual SPF is lower than the claimed SPF. No quantitative conclusion can be drawn due to the fact that SPF is based on UVB protection, whereas skin cancer can also be caused by UVA radiation. Moreover, the results obtained using this *in vitro* method are corrected to correlate more accurately with the *in vivo* reference method. This makes it impossible to accurately quantify the actual protection that the sunscreen product offers against both UVA and UVB radiation.

Skin cancer is a serious health effect and sunburn leads to an increased risk of skin cancer later in life. However, the risk of skin cancer is determined by multiple factors and, in relation to the use of sunscreen products, the number of occasions on which the skin is burned, the type of UV radiation and the skin type also play a role.

If the SPF measured is lower than the SPF claimed on the packaging, the consumer is misled and this discrepancy contributes to an increased risk of developing skin cancer later in life.

The reservations expressed about the *in vitro* method employed preclude the possibility of a quantitative exposure assessment or risk characterisation.

What are the risks to the consumer from the harmful effects of UV radiation based on the available product information regarding sunscreen products?
- *How is the system of classification/categorisation of sunscreen products structured?*

Sunscreen products are classified on the basis of the degree of UVB protection they offer (SPF). According to Recommendation 2006/647/EC, sunscreen products must also offer UVA protection, equivalent to at least one third of the UVB protection.

- *What methods are available for determining the SPF, and what are their advantages and disadvantages?*

In vivo reference methods measure UVA and UVB protection based on observation of an acute effect in test subjects: the erythemal response to UVB radiation and the tanning of the skin by UVA radiation. It is unclear how this acute effect relates to the level of UV protection and protection against negative health effects in the long term, such as premature skin ageing and skin cancer. These *in vivo* methods are only tested on a single specific skin type and the actual UV protection for lighter skin types is therefore lower than measured. Another disadvantage is that from an ethical viewpoint, it is undesirable to expose test subjects to harmful UV radiation.

In vitro methods are also available. The advantage of these methods is that they enable the entire spectrum of UV radiation to be quantitatively measured. The step involving irradiation with a UV lamp also provides a quantitative measurement of the stability of UV filters during the period of use. The disadvantage of these *in vitro* methods is that they cannot take into account the interaction between the sunscreen product and the skin. Moreover, the results obtained are corrected so that they correlate more accurately with the results obtained using the *in vivo* reference methods.

For both the *in vivo* and *in vitro* methods, the specified quantity of the product specified is not representative for the quantity that consumers actually apply to their skin.

Advice from BuRO

To the State Secretary for Youth, Prevention and Sport

- Contribute actively to the revision of Recommendation 2006/647/EC. Ensure that a uniform SPF is produced that will serve as a realistic measurement for both UVA and UVB protection.
- Inform consumers about the meaning and the importance of UVA and UVB protection.
- Ensure that *in vitro* methods are specified as reference methods for measuring the UV protection provided by sunscreen products with the following focal points:
  - The quantity applied should be representative for how consumers actually used the product;
  - Stability of the UV filters during the recommended period of use.

To the Inspector-General of the NVWA:

- Inform the industry about the sometimes considerable discrepancy in results between the *in vivo* reference method and the double plate *in vitro* method.
- Enforce if the declared SPF values of sunscreen products are too low.

Yours sincerely,

Prof. Dick T.H.M. Sijm
Director of the Office for Risk Assessment and Research

Office for Risk Assessment & Research

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3 September 2024

Our reference
2024-010061093

Substantiation

Introduction

Ultraviolet (UV) radiation from the sun can cause skin cancer. According to KWF (the Dutch Cancer Association), skin cancer is the most commonly occurring type of cancer in the Netherlands. The number of people in the Netherlands suffering from skin cancer is growing faster than expected. More than 70,000 patients are diagnosed with skin cancer each year (77,000 in 2023). It is therefore important to protect the skin against UV radiation. This can be achieved by restricting exposure to sunlight, for example by staying out of the sun, in particular between 12.00 and 15.00. It is also advisable to wear sufficient clothing and to cover your head. Another way to protect the skin against UV radiation is by using sunscreen products.

Sunscreen products are cosmetic products that are available on the market in various forms: as sprays, creams, powders, sticks and oils. Sunscreen products contain UV filters, substances which protect the skin against UV radiation by absorbing, scattering or reflecting certain types of UV radiation. In total, 34 UV filters are permitted in sunscreen products in the EU according to the Cosmetics Regulation (EC) no. 1223/2009[1] (see UV filters).

Approach

With a view to providing a thorough and accurate response to the research questions, the study began by examining the harmful effects of UV radiation. The study then addressed the definition of sunscreen products – the relevant legal framework, the requirements imposed and the test methods available – before considering other factors with a possible impact on the UV protection offered by these products. Finally, an assessment was made of the potential health risks arising from products with a lower SPF than claimed by the manufacturer.

The first step towards addressing these issues was taken in February 2023, when the following questions about the safety of sunscreen products with an inaccurate SPF claim were put to the RIVM WFSR Front Office Food and Product Safety (FO, 2023):

1. What are the effects of UVA and UVB radiation on human skin? What effects are viewed as harmful to health? How serious are these health effects and is there is a dose-response relationship? Is there a relationship between these health effects?
2. At what deviation from the claimed UVA and UVB protection factor does a health risk occur? The response should take into account the relationship between the prescribed quantity of sunscreen product (2 mg/cm^2) and actual use. The study should at least include sunscreen products with a claimed SPF of 30 and 50. Where possible, indicate at which SPF (determined according to the standard) a product no longer has a protective effect.
3. Identify vulnerable target groups and indicate the extent to which they run a greater health risk, specifying the health effect in each case.
4. Is there a difference between exposure to UVA and UVB radiation originating from natural sunlight and a sunbed? If so, how does this affect the protection offered by sunscreen products? How does the protection offered differ for various skin types?

An additional literature study was also conducted by BuRO, using various search terms across a range of databases (see the table in Annex 1).

[1]. Regulation (EC) No. 1223/2009 of the European Parliament and of the Council of 30 November 2009 on cosmetic products. PB L 342 of 22.12.2009, pp. 59-209.

Hazard identification

UV radiation

UV radiation is part of the electromagnetic spectrum with wavelengths of between 100 nm and 400 nm, and is divided into three types: UVA, UVB and UVC (FO, 2023). UVC (wavelengths between 100 nm and 280 nm) from the sun is entirely blocked by the ozone layer and does not reach sea level (Kciuk et al., 2020; Sander et al., 2020). The wavelength of UVA is between 315 nm and 400 nm, and that of UVB between 280 nm and 315 nm. Most UVB is blocked by the ozone layer, while UVA remains largely unaffected. As a result, solar radiation at sea level consists of 95% UVA radiation and 5% UVB radiation. To gain a greater insight into the human health risks of the different types of UV radiation from the sun, it is important to understand the structure of human skin (see Figure 1).

Human skin is made up of three layers: the outer skin (epidermis) consisting of several layers (stratum corneum, stratum lucidum, stratum granulosum, squamous cell layer and basal cell layer), the dermis and the hypodermis.

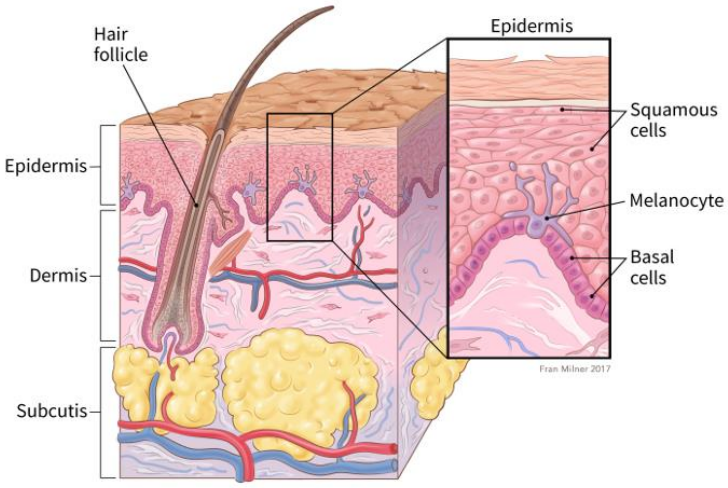

Figure 1: Structure of the skin and the different skin layers[2]

UVA radiation
UVA radiation causes the skin to age and can cause various forms of skin cancer. UVA radiation penetrates deeper into the skin than UVB radiation, as far as the dermis. However, UVA radiation has lower energy levels than UVB radiation and consequently cannot cause direct DNA damage (Sander et al., 2020). UVA radiation can cause photodegradation – the breakdown of molecules under the influence of light – which can subsequently lead to an increase in the production of ROS (Reactive Oxygen Species, oxygen radicals). ROS can have a harmful effect on DNA, which can result in mutations and subsequently cancer (Armstrong & Kricker, 2001; Gordon, 2013; Marionnet et al., 2014).

UVB radiation
The main negative health effects of UVB radiation are erythema (reddening of the skin) and different forms of skin cancer. Compared with UVA radiation, UVB radiation penetrates the exposed skin less deeply: most is absorbed by the epidermis and only a small proportion reaches the stratum basale with its stem cells (Gordon, 2013). UVB radiation has so much energy that it can damage DNA directly. If the affected cells are not successfully repaired, this can lead to the formation of skin cancer.

[2] https://www.cancer.org/cancer/types/basal-and-squamous-cell-skin-cancer/about/what-is-basal-and-squamous-cell.html

Hazard characterisation

Health effects of UVA and UVB radiation

Erythema
Exposure of the skin to UVB radiation leads to erythema, an acute subcutaneous inflammatory reaction which generally lasts between 4-7 days and is characterised by redness of the skin (sunburn). Cells that are irreparably damaged by UV radiation can release signal substances (cytokines) which activate a process called vasodilation so that the damaged cells can be cleared away. This is what causes the redness of the skin. In the event of severe erythema, the epidermis (or part of it) is shed (peeling). For most people, erythema is the first noticeable health effect of UV radiation on the skin and occurs shortly after exposure. It has therefore become the reference effect for informing people how relevant it is to protect themselves against the sun and about the effectiveness of sunscreen products (World Health Organization, 2002).

Skin cancer
The most common forms of skin cancer in the Netherlands are basal cell carcinoma, squamous cell carcinoma and melanoma. These forms of skin cancer are briefly explained below.

Basal cell carcinoma (BCC)
BCC is the most common form of skin cancer and has now been linked in multiple studies to erythema and total UV dose (Armstrong & Kricker, 2001; Corona et al., 2001; Pelucchi et al., 2007). It is easily treatable, grows relatively slowly and rarely metastasises. This form of skin cancer occurs in the basal cells in the bottom layer of the epidermis. Actinic keratosis, rough patches on the skin caused by the sun, are often associated with BCC (Pelucchi et al., 2007).

Squamous cell carcinoma (SCC)
SCC is the second most common form of skin cancer and is associated with chronic UV exposure, and to a lesser extent with erythema, but is strongly linked to actinic keratosis (Armstrong & Kricker, 2001). SCC usually remains localised but can metastasise, in particular to the lymph nodes. It also spreads more quickly than BCC. This form of skin cancer occurs in the top layer of the epidermis, in the squamous cells just below the stratum corneum.

Melanoma
Melanoma is the most aggressive form of skin cancer and is less common than BCC and SCC. Melanoma grows in pigment cells, which are found in the epidermis, just above the dermis. Melanoma is primarily associated with excessive exposure to the sun and with erythema (Gandini et al., 2005). Serious abnormalities in a mole or a newly occurring mole that changes form is generally a melanoma.

Amplification and prevalence of skin cancer due to exposure to UV radiation
Biological amplification factors have been derived for the three most commonly occurring types of skin cancer (Slaper et al., 1996). These take the form of a coefficient and indicate the percentage change in the incidence of the relevant skin cancer type for each 1% increase in UV dose, assuming a small change in UV dose. This biological amplification factor for BCC has a value of 1.4, for SCC 2.5 and for melanoma 0.6 (Slaper et al., 1996).

Structural use of a product with SPF Y (actual value) for which SPF X (expected value) is marked on the packaging results in an amplification of the prevalence of skin cancer by a factor of $(X/Y)^{\lambda}$, whereby λ is the biological amplification factor (Slaper et al., 1996). This formula shows the amplification of the prevalence of skin cancer, but not the risk of skin cancer itself. As regards the actual risk, highly diverse factors (e.g. genetics, behaviour, location and climate) all play a role and make the variation within the population very large.

By way of illustration, Table 1 provides an overview of the calculated increase in the prevalence of the various types of skin cancer in the event of a deviating SPF from a sunscreen product with a claimed SPF of 30. For SCC in particular, the calculated prevalence rises considerably in the event of a deviating SPF. If a sunscreen product does not offer the UV protection consumers may assume based on the label, the risk of the occurrence of skin cancer rises.

Table 1: Amplification of prevalence of skin cancer in the event of a deviating SPF of a sunscreen product with claimed SPF of 30

SPF measured	BCC	SCC	Melanoma
30	1	1	1
20	2	3	1.3
10	5	16	1.9
5	12	88	2.9

Premature skin ageing
Excessive exposure to UV radiation, in particular UVA radiation, leads to premature ageing of the skin. The skin loses collagen, which has a detrimental effect on its elasticity and results in wrinkles.

Vitamin D
Sunlight is an important source of vitamin D, which the body produces when the skin is exposed to UVB radiation. Vitamin D ensures strong bones and muscles and keeps the immune system active and healthy.

SPF (Sun Protection Factor) and skin types

SPF refers to the ratio between the minimum erythemal dose on skin protected by a sunscreen product and the minimum erythemal dose on the same skin without protection. At present, SPF is mainly determined by exposing test subjects to UV radiation. The SPF is calculated by determining the ratio between the minimum erythemal dose on protected skin, with sunscreen product, and unprotected skin, without sunscreen product (Ionescu & Gougerot, 2007). Erythema is primarily caused by UVB radiation, which means that SPF is a measure specifically for UVB protection. First introduced by German physicist Rudolf Schulze, it was originally referred to as the 'Schulze Factor'. The term SPF was first coined around 1960 and went on to be adopted as the measurement for sunscreen products by the American Food and Drug Administration (FDA) in 1978 (FDA & HHS, 1999).

The Standard Erythemal Dose (SED) is a unit that offers an objective measurement for the erythema-weighted dose whereby 1 SED equivalent is to an erythemal radiant exposure of 100 J/m^2. For erythema, there is a threshold dose, known as the Minimal Erythemal Dose or MED (Fitzpatrick, 1988), which varies from person to person.

For the *in vivo* SPF method, different skin types are prescribed and determined for test subjects. The most widely used scales are the Fitzpatrick scale and the Individual Typology Angle (ITA). Fitzpatrick (Fitzpatrick, 1988) produced a classification of 6 skin types based on the MED value and capacity to adapt to UV radiation exposure. Characteristic values for the Fitzpatrick skin types are shown in Table 2. The burning of the skin in this table is based on an observation 24 hours after exposure and the tanning 7 days after exposure. This varies from skin type I to VI.

Table 2: Classification of Fitzpatrick skin types (Fitzpatrick, 1988)

Fitzpatrick skin type	Reaction to UV exposure	Reference	MED [SED]
I	Always burns, never tans	Very pale skin, red or blond hair	2 to 3
II	Usually burns, tans minimally	Pale skin, dark blond to chestnut brown hair	2.5 to 3.5
III	Sometimes burns, tans averagely	Tanned skin, dark hair	3 to 5
IV	Rarely burns, tans more than average	Dark/Brown, Mediterranean, light Asian	4.5 to 6
V	Never burns, always tans	Dark, Asian	6 to 10
VI	Never burns, no visible colour change	Afro Caribbean	10 to 20

People's skin colour is determined by the total quantity of melanin, the relationship between the brown-black eumelanin and the yellow-red pheomelanin, and its distribution across the epidermis. The ITA° classification is an objective classification of skin colour type. A reflection colorimeter is used to measure the quantity of light reflected: clarity (from white to black) and yellow/blue (Chardon et al., 1991). Based on these measurements, the ITA° is calculated and the skin type can be determined according to Table 3.

Table 3: ITA° skin type classification (Chardon et al., 1991)

Individual Typology Angle	Skin classification
ITA° > 55°	Very light
41 ° < ITA°< 55°	Light
28° < ITA° < 41°	Intermediate
10° < ITA° < 28°	Tan
-30° < ITA° < 10°	Brown
ITA° < -30°	Dark

Legal framework

Sunscreen products

In the EU, sunscreen products fall into the category of cosmetic products and must comply with the Cosmetics Regulation (EC) No. 1223/2009. Article 3 states that cosmetic products must be safe for public health under normal or reasonably foreseeable conditions of use. The European Commission published Recommendation 2006/647/EC[3] on the efficacy of sunscreen products and the claims made relating thereto. This recommendation specifies that sunscreen products must offer protection against both UVB radiation and UVA radiation, and that the UVA protection must be equivalent to at least one third of the UVB protection. Sunscreen products must have an SPF of at least 6.

The test method that should be used to determine the SPF (UVB protection) is the International Sun Protection Factor Test Method. Table 5 provides an overview of all methods for determining UV protection of sunscreen products.

According to Recommendation 2006/647/EC, the SPF of sunscreen products must be stated on the label of the sunscreen products as indicated in Table 4.

[3] Commission Recommendation 2006/647/EC of 22 September 2006 on the efficacy of sunscreen products and the claims made relating thereto. PB L 265 of 26.9.2006, pp. 39-43.

Table 4: SPF declaration and protection in accordance with Recommendation 2006/647/EC

Indicated SPF	Measured SPF	Indicated category
6	6-9.9	Low
10	10-14.9	Low
15	15-19.9	Average
20	20-24.9	Average
25	25-29.9	Average
30	30-49.9	High
50	50-59.9	High
50+	>60	Very high

In addition to the SPF, the label must also state whether the product offers protection in the category 'low', 'average', 'high' or 'very high' (European Commission, 2006).

Recommendation 2006/647/EC further states that sunscreen products must display warnings to the effect that they do not offer total protection. Other warnings should also be displayed on the label such as: 'Do not stay too long in the sun even while using a sunscreen product'; 'Keep babies and young children out of direct sunlight'; 'Reapply frequently to maintain protection, especially after perspiring, swimming or towelling'. Sunscreen products should also carry instructions for use that will ensure that the claims made for the protection offered by the product can be achieved.

UV filters are added to sunscreen products. These protect the skin by absorbing, scattering or reflecting UV radiation, or a combination of the three. According to Article 14 of the Cosmetics Regulation (EC) No. 1223/2009, only UV filters listed in Annex VI to the Regulation may be used, in compliance with the conditions imposed on them such as a restriction, a maximum content or the stipulation that they not be used in spray form.

The Claims Regulation (EU) No. 655/2013[4] specifies that claims regarding cosmetic products must be correct, fair, clear and understandable. These claims must also be substantiated by proof of the effect, to be included in the product information file as intended in Article 11 of Regulation (EC) No. 1223/2009. The Claims Regulation also relates to the claimed SPF. The product information file of the sunscreen product must therefore contain proof to substantiate the claimed SPF.

Test methods for the efficacy of sunscreen products

According to Section 12 of Recommendation 2006/647/EC, claims indicating UVB and UVA protection should be made only if the protection equals or exceeds the levels set out in the Recommendation (Table 4).

Section 10 of Recommendation 2006/647/EC states the following:

- For UVB: UVB protection of sun protection factor 6 as obtained in application of the International Sun Protection Factor Test Method (2006) or an equivalent degree of protection, obtained with any *in vitro* method.
- For UVA protection: protection against UVA radiation with a UVA protection factor equivalent to 1/3 of the sun protection factor, as obtained in application of the 'persistent pigment darkening' method or an equivalent degree of protection obtained with any *in vitro* method.

[4] Commission Regulation (EU) no. 655/2013 of 10 July 2013 laying down common criteria for the justification of claims used in relation to cosmetic products. PB L 190, 11.7.2013, pp. 31-34.

The *in vivo* reference methods are described for both UVB and UVA protection. The International Sun Protection Test Method for UVB protection, dating from 2006, has now been replaced by ISO 24444. The 'persistent pigment darkening' test for UVA protection has been replaced by ISO 24442.

According to the Recommendation, *in vitro* tests are preferable provided that they deliver equivalent results, due to the ethical concerns raised by the *in vivo* method.

A number of different *in vitro* methods are now also available for measuring UVA and UVB protection. These have to be equivalent to both reference methods, meaning that correction factors must be applied to the *in vitro* results, so that they correlate well with the *in vivo* reference method.

Table 5 provides an overview of these methods, along with a short description. These methods are then explained in greater detail.

Table 5: Overview of methods for measuring UV protection of sunscreen products

Method	**Substrate**	**UV radiation**	**Measurement**	**Application quantity (mg/cm²)**	**Reservations**
ISO 24444 2019 – Reference method *in vivo*	Test subject	UVB	Observation of reddening skin	2	- Exposure of test subjects to UV radiation
					- Reliability of readout from the skin
					- Tested on a single skin type
					- Reproducibility of application
ISO 24442 2022 – Reference method *in vivo*	Test subject	UVA	Observation of tanning skin	2	- Exposure of test subjects to UV radiation
					- Reliability of readout from the skin
					- Tested on a single skin type
					- Reproducibility of application
ISO 24443 2021 *in vitro*	Sandblasted PMMA plate	UVA	Permeating UV radiation	1.2	- Initial SPF must first be determined using ISO method
					- Correction factor applied to ensure correlation between SPF per plate and initial SPF
Double plate method (ISO/DIS 23675) *in vitro*	Sandblasted PMMA plate and PMMA plate	UVA and UVB	Permeating UV radiation	1.3	- No interaction between skin and sunscreen
					- Reproducible application across the plates
					- Results corrected to correlate with reference method
HDRS (ISO/DIS 23698) *in vivo* and *in vitro*	Test subject and PMMA plate	UVA and UVB	UVA reflection Permeation UVB radiation	2 (test subject) 1.2 and 1.3 (plate)	- Interaction between skin and sunscreen only for UVA
					- Reproducibility of application
					- Results corrected to correlate with reference method
in silico	Computer model	UVA and UVB	Calculation based on content of UV filters	N/A	- No interaction between skin and sunscreen
					- Concentrations of UV filters must be known
					- Effect of other substances not included

ISO 24444: UVB in vivo (SPF)
Recommendation 2006/647/EC stipulates ISO 24444 as the reference method for determining the SPF of a sunscreen product. This is an *in vivo* method in which test subjects are exposed to UV radiation (290-400 nm, UVA and UVB radiation), primarily UVB radiation, with and without a sunscreen product (Zou et al., 2022). The test subjects must have an average ITA° of between 41° and 55° (light skin type). The dose required to produce an erythemal response on the unprotected skin (MED unprotected) and on skin protected with sunscreen product (MED protected) is then determined. This is expressed as the intensity of the sun simulator (W/m^2) and the dose per individual (J/m^2). The prescribed quantity of sunscreen product is applied ($2\ mg/cm^2$), based on the lowest possible value whereby the results proved reproducible (Cole, 2014; Petersen & Wulf, 2014). In this test, the skin is exposed to different doses of UV radiation, after which the skin is visually assessed between 16 and 24 hours after exposure. For each individual test subject, an SPF is calculated as follows:

SPF = MED protected / MED unprotected

ISO 24442: UVA in vivo
Recommendation 2006/647/EC stipulates ISO 24442 as the reference method for measuring UVA protection of sunscreen products. This method focuses on the 'persistent pigment darkening' (PPD): the coloration (tanning) of the skin. Analogously to ISO 24444, this *in vivo* method also relies on a visual assessment of the skin, but after 2-4 hours and primarily for UVA radiation (340-400 nm). The same quantity of sunscreen product is applied ($2\ mg/cm^2$). The values of the dose for coloration are compared with the minimal persistent pigment darkening dose (MPPDD). This test uses subjects with a skin type that tans relatively easily: ITA° between 18° and 42° (see Table 3).

ISO 24443: UVA in vitro
ISO 24443 is an *in vitro* method for UVA protection which measures the UVA transmission by applying a thin film of sunscreen product to a roughened polymethyl acrylate (PMMA) plate. These plates are exposed to a specific dose of UV radiation, which also allows the photostability of the sunscreen product to be included in the evaluation. The quantity applied is $1.2\ mg/cm^2$. This method can also be used for oil or spray sunscreen products. In that case, the spreading of the product across the plate by a robot finger is done slightly differently than with creams. With an oil, the product is spread in circles. Sprays first need to be degasified and then acclimatised for 24 hours, before being spread on the plate. Each set of transmission data for sunscreen products is mathematically adjusted, so that the *in vitro* SPF data correlate with the *in vivo* SPF values.

Hybrid Diffuse Reflectance Spectroscopy (HDRS): UVA in vivo and UVB in vitro
This method combines an *in vivo* DRS (diffuse reflectance spectroscopy) measurement on the skin and an *in vitro* transmission measurement of sunscreen product on a roughened PMMA plate (Rohr et al., 2018). The test subjects must have an average ITA° of between 41° and 55° (light skin type). In the UVA *in vivo* method, reflection of UV radiation is measured on a skin surface area of $36\ cm^2$, with and without sunscreen product and $2\ mg/cm^2$ of the product is applied. The reflection is measured at a wavelength of 310-400 nm (UVA radiation). As this *in vivo* measurement does not focus on the erythemal response, a high radiation dose is not required. Instead, the reflection of the UVA radiation on the skin is observed, based on total reflection.

Due to the high UVB absorption of the stratum corneum and the epidermis, human skin reflects insufficient UVB radiation for absorption measurements. For UVB protection, therefore, an *in vitro* measurement is carried out, comparable to ISO 24443, at a wavelength of 290-400 nm (UVA and UVB radiation). The

transmission of this UV radiation is measured through a film of sunscreen product, applied to a PMMA plate. To obtain a complete UV absorption spectrum for the sunscreen product, the *in vitro* absorption is scaled to correlate with the DRS absorption values, at which point the *in vitro* UVB component is mathematically coupled to the UVA component.

At present, this method has the status of a draft ISO standard (ISO/DIS 23698) but is expected to be published as a full ISO standard within one year.

Double plate method: UVA and UVB in vitro
The double plate method makes use of PMMA and sandblasted PMMA plates, in line with protocol No. 26 (Cosmetics Europe, 2022). In this method, a set quantity of the sunscreen product is applied by a robot finger: 1.3 mg/cm^2 on the PMMA plate and 1.2 mg/cm^2 on the sandblasted plate. These quantities were determined by comparing this method with a number of studies that used the ISO 24444 *in vivo* reference method (Pissavini et al., 2018; Pissavini et al., 2020). Following an initial measurement of the UV transmission with the sunscreen product, the initial *in vitro* SPF and radiation dose are calculated. After the initial measurement, each pair of plates treated with sunscreen product is irradiated with the calculated maximum radiation dose. The UV absorption is then remeasured to determine the photostability of the sunscreen product. The final *in vitro* SPF is calculated based on the transmission measurement after irradiation.

At present, this method has the status of a draft ISO standard (ISO/DIS 23675) but is expected to be published as a full ISO standard within one year.

In silico
A computer model can be used to calculate the SPF of a sunscreen product based on the levels of UV filters present. This is known as the in silico method[5] (Herzog & Osterwalder, 2011). Precisely how this value is calculated is unclear. To enable use of this method, the concentrations of UV filters in the sunscreen product must be known. This requires information on how the product is made but can also be achieved through chemical analysis of the ingredients. The in silico method is primarily used by manufacturers of sunscreen products, mainly because they have full access to the ingredient list.

Reservations about the various test methods

The various test methods described above are all used to determine the SPF of a product. BuRO expresses the following reservations about these methods.

In vivo methods (ISO 24444 and ISO 24442):

1. Ethical concerns: exposing humans to additional UV radiation with skin cancer as a possible result.
2. Financial drawbacks: a minimum 10 subjects is required, which makes it very expensive for smaller brands to bring affordable sunscreen products to market.
3. Reliability: assessing the reddening or tanning of the skin is subjective and differs between test subjects. The test is also carried out indoors with a UV lamp and does not provide an accurate representation of sunlight.
4. Not representative for the entire population: the test subjects selected have a skin type with an ITA° of less than 55°. For people with darker skin, protection against UVA radiation is the crucial factor, because their darker skin already offers them protection against UVB radiation.
5. Reproducibility of application: the quantity of 2 mg/cm^2 has been determined for application to ensure sufficient reproducibility of the test. This quantity is not based on the quantity that consumers apply in

[5] sunscreen-optimizer.com (DSM SUNSCREEN OPTIMIZER™)

practice, which has been estimated at between 0.4 and 1 mg/cm^2 (Petersen & Wulf, 2014).

In vitro methods (ISO 24443, double plate method, HDRS)

1. Substrate: no substrate has yet been found that successfully simulates the interaction between the product and human skin. Consequently, it is unknown whether the measurement results correspond with the actual UV transmission.
2. Reproducibility of application: correctly and consistently applying the sunscreen product to the plate/substrate is important for reproducibility. Robot arms are now available for this process.
3. Use of correction factors to ensure that the results correlate with the *in vivo* reference method. It is therefore unclear what UV protection is actually offered.

Exposure assessment

Little is known about the extent of human exposure to UV radiation in the Netherlands. The sun is the main source of UV exposure for the population (Slaper et al., 2017). The sun's intensity and the related UV radiation is greater when the sun is high in the sky between 12.00 and 15.00 on relatively cloudless days in spring and summer. Damage to the ozone layer and climate change may have an impact on the level of UV radiation that reaches the Earth's surface (Slaper et al., 2017). Exposure to UV radiation from the sun has probably risen in recent years. This may be partly due to a rise in the number of hot days, in combination with an increase in the amount of leisure time that people spend outdoors, wearing clothes that cover less skin. In addition, the quantity of UV radiation has risen in the Netherlands over the past few decades (CBS, et al., 2023).

For the assessment of exposure to UV radiation, BuRO made use of the NVWA's results on the UV protection offered by sunscreen products, measured using a variety of test methods. These results were then compared with the claimed UV protection in the product information. Other factors with an impact on UV protection of sunscreen products also formed part of the assessment.

Results of NVWA study of sunscreen products

In 2023, as part of the NVWA study, 54 sunscreen products were sampled, with a claimed SPF of 30 or higher. The NVWA laboratory used the *in vitro* double plate method to determine the SPF of these samples. This method was validated and the measurements were conducted in triplicate, in line with the certified SPF standards. In addition to the double plate method, a further step was added in which the sunscreen products were exposed to maximum irradiation based on the initial SPF after the irradiation the SPF was remeasured. This determine the photostability of the UV filters.

In addition, an external laboratory carried out an *in vivo* SPF measurement of 13 of the samples according to the ISO 24444 standard (UVB reference method). Another external laboratory determined the levels of UV filters for all 54 samples. Based on these findings, the SPF for each sunscreen product was then calculated using the in silico method.

All these results are shown in Table 8 in Annex 2. The results obtained with the double plate *in vitro* method showed that, prior to irradiation, 26 sunscreen products (48%) had a lower SPF than stated on the label. Following irradiation, 36 sunscreen products (67%) had a lower SPF than claimed. In the case of 2 products, the SPF measured was below 6, which means that they did not qualify as a sunscreen product under the criteria stated in Recommendation 2006/648/EC. In most cases, the SPF measured after irradiation was lower than

the SPF prior to irradiation, which is an indication of the instability of the UV filters in the sunscreen products.

For the UVA protection (UVA-PF), measured using the same double plate method, the majority of the sunscreen products were shown to meet the minimum requirement of one third of the value of UVB protection. In total, 16 of the sunscreen products tested (30%) complied with the requirement for both UVB and UVA protection, using the double plate *in vitro* method.

The in silico calculations indicated that 47 sunscreen products (87%) have a lower SPF than claimed.

The results for the samples in which the *in vivo* SPF was also measured are summarised in Table 6. This table shows the following results for each sample number tested:

- SPF label: The UVB protection factor stated on the label of the sunscreen product.
- *In vitro* SPF prior to irradiation. The initial SPF (UVB protection) determined by the NVWA laboratory using the double plate method.
- *In vitro* SPF following irradiation. The SPF (UVB protection) after the plate with sunscreen product is exposed to maximum irradiation with UV light.
- *In vivo* SPF: UVB protection measured with the *in vivo* reference method ISO 24444.
- In silico SPF: UVB protection calculated based on the UV filter levels determined by analysis.

Table 6: Results of the NVWA study of SPF (UVB protection) of sunscreen products determined according to various test methods

Sample number	**SPF label**	**SPF *in vitro* prior to irradiation**	**SPF *in vitro* following irradiation**	**SPF *in vivo***	**SPF in silico**
87360156	50	7.3	7.2	44.8	15
87173682	30	10.9	8.0	20.8	15.6
87173704	30	18.9	16.5	42.3	28.6
87173828	30	9.3	9.2	26.4	13.8
87420213	50	24.5	13.5	45.8	27.8
87360369	50+	3.5	3.2	10.2	5
87377695	30	20.0	19.2	38.6	14.9
87377709	30+	1.7	1.7	5.7	2.7
87420434	50+	75.7	58.3	61.4	38.7
87173917	30	6.4	6.0	14.8	13.4
87101223	50	58.5	27.4	64.5	36.8
87360083	30	22.1	20.6	42.6	28.3
87360148	50	7.7	7.6	15.4	16

The 3 methods (*in vitro, in vivo* and in silico) deliver differing results (Table 5). Generally speaking, the SPF *in vitro* was the lowest, the SPF *in vivo* highest and the SPF in silico somewhere in between. Although the *in vivo* method delivers higher SPF values as compared with the *in vitro* or in silico method, 8 of the 13 samples investigated using these methods have a lower SPF than stated on the label.

Other factors that impact on the UV protection of sunscreen products

A range of factors have an impact on the UV protection offered by sunscreen products. Some of these are product-related, such as the effect and stability of the UV filters. However, the consumer's use of the product also affects the UV protection offered, such as the quantity they apply to their skin and the extent to which they read and understand the label. The sensitivity of specific groups is another factor. A number of these factors are explained in more detail below.

Anti-inflammatories in sunscreen products
In addition to offering protection against UV radiation, various UV filters have anti-inflammatory effects (Couteau et al., 2012; Couteau et al., 2014). Couteau et al. tested 21 UV filters, 13 of which demonstrated anti-inflammatory effects (Couteau et al., 2012). These effects slow the erythemal response caused by inflammation. Anti-inflammatories therefore suppress sunburn, which acts as a warning sign of DNA damage. In other words, anti-inflammatories counter the visible signs of the damage without alleviating the damage itself (Couteau et al., 2012; Couteau et al., 2014).

Peres et al. observed that adding the antioxidant ferulic acid to sunscreen products with the UV filters ethylhexyl triazone and bis-ethylhexyloxyphenol methoxyphenyl triazine creates a synergetic effect (Peres et al., 2018); the SPF increases to 37% and the UVA protection to 26% by suppressing inflammatory reactions. Sauce et al. demonstrated that ferulic acid reduces skin inflammation and vasodilatation (Peres et al., 2018; Sauce et al., 2021).

Anti-inflammatory substances in sunscreen products increase the SPF measured *in vivo* but in reality the sunscreen products are less effective at preventing exposure to UV radiation than claimed.

In the NVWA study conducted in 2023, *in vivo* measurements for a number of sunscreen products revealed a major discrepancy between the *in vivo* and *in vitro* measurements of SPF. One possible explanation for this discrepancy is the presence of anti-inflammatory substances in the products tested, which prevented the reddening of the skin, even though the UV protection was lower than claimed on the label. Further studies into the presence of anti-inflammatory substances in these sunscreen products are needed.

Stability of UV filters
Some UV filters in sunscreen products are not stable and are broken down under the influence of sunlight. If a UV filter in a sunscreen product is unstable, the sunscreen product offers protection for a shorter period than indicated by the claimed SPF, and following exposure to the sun, the effect of the sunscreen product declines rapidly (Damiani et al., 2010; Jesus et al., 2022). As a result, consumers are less protected than they expect based on the claimed SPF and may therefore be exposed to more UV radiation. Given the potentially serious consequences of the harmful effects of UV radiation, it is important to know the stability of the UV filter and to reflect that knowledge in the claimed SPF (Damiani et al., 2010).

Annex 2, Table 8 shows that after irradiation, the measured SPF of 15 sunscreen products (28%) decreased by 20% or more. For 2 sunscreen products (4%), the decrease in SPF measured following irradiation was more than 50%.

Efficacy of UV filters
Annex VI to the Cosmetics Regulation (EC) No. 1223/2009 lists a total of 34 admissible UV filters, both organic and inorganic. The organic UV filters include ethylhexyl salicylate, butyl methoxydibenzoylmethane and ethylhexyl triazone. The effect of organic UV filters is based on the absorption of UV light. The inorganic UV filters include titanium dioxide and zinc oxide. These metal oxides

mainly protect the skin by reflecting or scattering light. All UV filters in a product must be stated on the label.

The Scientific Committee on Consumer Safety (SCCS) assesses UV filters for safety but not efficacy (The SCCS notes of guidance for the testing of cosmetic ingredients and their safety evaluation). SCCS publishes its findings on a cosmetic ingredient as an opinion, which forms the basis for a European Commission decision on whether to include the UV filter in Annex VI and whether it should be subject to restrictions or conditions. The SCCS website lists a number of published opinions on UV filters.

How consumers use the product
The way consumers use a sunscreen product has an impact on the level of protection. For the *in vivo* reference methods, a quantity of 2 mg/cm^2 is applied; for the *in vitro* methods, 1.2-1.3 mg/cm^2 is the norm. Several studies of consumer behaviour have found that consumers usually apply far less (Autier et al., 2001; Neale et al., 2002; Heerfordt, 2018). According to Petersen et al. consumers apply between 0.39 and 1 mg/cm^2 (Petersen & Wulf, 2014). Various studies have shown that applying a thinner layer of sunscreen product results in an exponential decrease in UV protection (Schalka et al., 2009; Kim et al., 2010).

Sensitive groups
Some groups of consumers have an even greater need to protect themselves against the harmful effects of the sun by using sunscreen products or sun protective clothing. They include children, people with skin type I and people with a compromised immune system.

Children are still growing meaning, their cells divide more quickly; this also applies to their skin cells. Dividing cells are more sensitive to DNA damage (Sarkany, 2021). There is a latency period between exposure of the skin to UV radiation and the occurrence of skin cancer (Diepgen & Mahler, 2002). This period varies for each skin cancer type but is generally 15 years (for melanoma) and up to 50 years (for SCC). As a consequence, exposure later in life carries less risk of developing skin cancer than exposure when young.

People with skin type I (pale skin, freckles, red hair) are more prone to sunburn than the other skin types; their skin burns more rapidly and does not adapt to the sun. A lack of pigment means that their skin builds up little protection against UV radiation.

People with a weakened immune system run a greater risk of skin cancer. This category includes recipients of donor organs, who have to take immunosuppressants to ensure that the transplanted organ is not rejected. Consequently, their immune system is less effective at recognising and repairing mutations, and skin damage (caused by UV radiation) can accumulate more easily. Relatively speaking, users of immunosuppressants therefore have an increased risk of developing skin cancer (FO, 2023).

Label information and consumer knowledge
The label of a sunscreen product contains information about the SPF, water resistance, UVA protection, ingredients and instructions for use. A study conducted in the United States in 2015 with 114 respondents revealed that 20% never read the information on the back of sunscreen products and 55% only read this information at the moment of purchase (Kong et al., 2015). Furthermore, only 38% of respondents knew how to determine whether a sunscreen product protects against the full spectrum of UV radiation. Only 34% indicated that they paid attention to the 'broad spectrum' (UVA and UVB) label. Only 43% knew what SPF stood for. This study led to the conclusion that more and clearer public information is needed regarding protection against UVA and UVB radiation.

Risk characterisation

It is not possible to carry out a quantitative exposure assessment due to the lack of uniformity among the methods for testing UV protection. Exposure of the skin to UV radiation is also difficult to assess, as it depends on multiple factors such as skin type and the intensity of the sun's rays. Nor is it possible to determine a threshold dose, as in many cases skin cancer only occurs years after exposure. This combination of factors rules out the possibility of providing a quantitative risk assessment.

References

Armstrong BK & Kricker A, 2001. The epidemiology of UV induced skin cancer. J Photochem Photobiol B, 63 (1-3), 8-18. Available online: https://doi.org/10.1016/s1011-1344(01)00198-1

Autier P, Boniol M, Severi G & Doré JF, 2001. Quantity of sunscreen used by European students. Br J Dermatol, 144 (2), 288-291. Available online: https://doi.org/10.1046/j.1365-2133.2001.04016.x

CBS, PBL & RIVM, 2023. UV-straling in Nederland, 1980-2022 (indicator 0220, versie 10, 2 augustus 2023). Available online: https://www.clo.nl/indicatoren/nl022010-uv-straling-in-nederland-1980-2022

Chardon A, Cretois I & Hourseau C, 1991. Skin colour typology and suntanning pathways. Int J Cosmet Sci, 13 (4), 191-208. Available online: https://doi.org/10.1111/j.1467-2494.1991.tb00561.x

Cole C, 2014. Sunscreens--what is the ideal testing model? Photodermatol Photoimmunol Photomed, 30 (2-3), 81-87. Available online: https://doi.org/10.1111/phpp.12095

Corona R, Dogliotti E, D'Errico M, Sera F, Iavarone I, Baliva G, Chinni LM, Gobello T, Mazzanti C, Puddu P & Pasquini P, 2001. Risk factors for basal cell carcinoma in a Mediterranean population: role of recreational sun exposure early in life. Arch Dermatol, 137 (9), 1162-1168. Available online: https://doi.org/10.1001/archderm.137.9.1162

Cosmetics Europe, 2022. Cosmetics Europe Recommendation n° 26 on the use of alternative methods to ISO24444:2019.

Couteau C, Chauvet C, Paparis E & Coiffard L, 2012. UV filters, ingredients with a recognized anti-inflammatory effect. PLoS One, 7 (12), e46187. Available online: https://doi.org/10.1371/journal.pone.0046187

Couteau C, Chauvet C, Paparis E & Coiffard LJ, 2014. Study of the persistence of the anti-inflammatory effect observed after application of preparations containing organic ultraviolet filters. Int J Pharm, 476 (1-2), 160-163. Available online: https://doi.org/10.1016/j.ijpharm.2014.09.024

Damiani E, Astolfi P, Giesinger J, Ehlis T, Herzog B, Greci L & Baschong W, 2010. Assessment of the photo-degradation of UV-filters and radical-induced peroxidation in cosmetic sunscreen formulations. Free Radic Res, 44 (3), 304-312. Available online: https://doi.org/10.3109/10715760903486065

Diepgen TL & Mahler V, 2002. The epidemiology of skin cancer. British Journal of Dermatology, 146 (s61), 1-6. Available online: https://doi.org/10.1046/j.1365-2133.146.s61.2.x

European Commission, 2006. Aanbeveling 2006/647/EG van de Commissie van 22 september 2006 inzake de doeltreffendheid van zonnebrandmiddelen en de vermeldingen dienaangaande. Publicatieblad, L265, 39-43.

FDA & HHS, 1999. Sunscreen drug products for over-the-counter human use; final monograph. Final rule. Fed Regist, 64 (98), 27666-27693.

Fitzpatrick TB, 1988. The validity and practicality of sun-reactive skin types I through VI. Arch Dermatol, 124 (6), 869-871. Available online: https://doi.org/10.1001/archderm.124.6.869

FO, 2023. Beoordeling van SPF zonnebrandproducten. V/093130. RIVM WFSR Front Office Voedsel- en Productveiligheid (FO) RIVM. Available online: https://www.rivm.nl/voedsel-en-voeding/veilig-voedsel/frontoffice-voedsel-en-productveiligheid/beoordelingen-front-office-voedsel-en-productveiligheid

Gandini S, Sera F, Cattaruzza MS, Pasquini P, Picconi O, Boyle P & Melchi CF, 2005. Meta-analysis of risk factors for cutaneous melanoma: II. Sun exposure. Eur J Cancer, 41 (1), 45-60. Available online: https://doi.org/10.1016/j.ejca.2004.10.016

Gordon R, 2013. Skin cancer: an overview of epidemiology and risk factors. Semin Oncol Nurs, 29 (3), 160-169. Available online: https://doi.org/10.1016/j.soncn.2013.06.002

Heerfordt IM, 2018. Sunscreen use at Danish beaches and how to improve coverage. Dan Med J, 65 (4).

Herzog B & Osterwalder U, 2011. In silico determination of topical sun protection. Cosm Sci Tech, 62, 1-8.

Ionescu MA & Gougerot A, 2007. Sun protection and sunscreen labeling--an update. Acta Dermatovenerol Croat, 15 (2), 92-95.

Jesus A, Sousa E, Cruz MT, Cidade H, Lobo JMS & Almeida IF, 2022. UV Filters: Challenges and Prospects. Pharmaceuticals (Basel), 15 (3). Available online: https://doi.org/10.3390/ph15030263

Kciuk M, Marciniak B, Mojzych M & Kontek R, 2020. Focus on UV-Induced DNA Damage and Repair-Disease Relevance and Protective Strategies. Int J Mol Sci, 21 (19). Available online: https://doi.org/10.3390/ijms21197264

Kim SM, Oh BH, Lee YW, Choe YB & Ahn KJ, 2010. The relation between the amount of sunscreen applied and the sun protection factor in Asian skin. Journal of the American Academy of Dermatology, 62 (2), 218-222. Available online: https://doi.org/https://doi.org/10.1016/j.jaad.2009.06.047

Kong BY, Sheu SL & Kundu RV, 2015. Assessment of Consumer Knowledge of New Sunscreen Labels. JAMA Dermatology, 151 (9), 1028-1030. Available online: https://doi.org/10.1001/jamadermatol.2015.1253

Marionnet C, Pierrard C, Golebiewski C & Bernerd F, 2014. Diversity of biological effects induced by longwave UVA rays (UVA1) in reconstructed skin. PLoS One, 9 (8), e105263. Available online: https://doi.org/10.1371/journal.pone.0105263

Neale R, Williams G & Green A, 2002. Application patterns among participants randomized to daily sunscreen use in a skin cancer prevention trial. Arch Dermatol, 138 (10), 1319-1325. Available online: https://doi.org/10.1001/archderm.138.10.1319

Pelucchi C, Di Landro A, Naldi L & La Vecchia C, 2007. Risk factors for histological types and anatomic sites of cutaneous basal-cell carcinoma: an italian case-control study. J Invest Dermatol, 127 (4), 935-944. Available online: https://doi.org/10.1038/sj.jid.5700598

Peres DD, Sarruf FD, de Oliveira CA, Velasco MVR & Baby AR, 2018. Ferulic acid photoprotective properties in association with UV filters: multifunctional sunscreen with improved SPF and UVA-PF. J Photochem Photobiol B, 185, 46-49. Available online: https://doi.org/10.1016/j.jphotobiol.2018.05.026

Petersen B & Wulf HC, 2014. Application of sunscreen--theory and reality. Photodermatol Photoimmunol Photomed, 30 (2-3), 96-101. Available online: https://doi.org/10.1111/phpp.12099

Pissavini M, Tricaud C, Wiener G, Lauer A, Contier M, Kolbe L, Trullás Cabanas C, Boyer F, Meredith E, de Lapuente J, Dietrich E & Matts PJ, 2020. Validation of a new in vitro Sun Protection Factor method to include a wide range of sunscreen product emulsion types. Int J Cosmet Sci, 42 (5), 421-428. Available online: https://doi.org/10.1111/ics.12625

Pissavini M, Tricaud C, Wiener G, Lauer A, Contier M, Kolbe L, Trullás Cabanas C, Boyer F, Nollent V, Meredith E, Dietrich E & Matts PJ, 2018. Validation of an in vitro sun protection factor (SPF) method in blinded ring-testing. Int J Cosmet Sci. Available online: https://doi.org/10.1111/ics.12459

Rohr M, Ernst N & Schrader A, 2018. Hybrid Diffuse Reflectance Spectroscopy: Non-Erythemal in vivo Testing of Sun Protection Factor. Skin Pharmacol Physiol, 31 (4), 220-228. Available online: https://doi.org/10.1159/000488249

Sander M, Sander M, Burbidge T & Beecker J, 2020. The efficacy and safety of sunscreen use for the prevention of skin cancer. Cmaj, 192 (50), E1802-e1808. Available online: https://doi.org/10.1503/cmaj.201085

Sarkany R, 2021. Sun protection. Medicine, 49 (7), 453-456. Available online: https://doi.org/https://doi.org/10.1016/j.mpmed.2021.04.011

Sauce R, Pinto CASdO, Velasco MVR, Rosado C & Baby AR, 2021. Ex vivo penetration analysis and anti-inflammatory efficacy of the association of ferulic acid and UV filters. European Journal of Pharmaceutical Sciences, 156, 105578. Available online: https://doi.org/https://doi.org/10.1016/j.ejps.2020.105578

Schalka S, dos Reis VM & Cucé LC, 2009. The influence of the amount of sunscreen applied and its sun protection factor (SPF): evaluation of two sunscreens including the same ingredients at different concentrations. Photodermatol Photoimmunol Photomed, 25 (4), 175-180. Available online: https://doi.org/10.1111/j.1600-0781.2009.00408.x

Slaper H, van Dijk A, den Outer P, van Kranen H & Slobbe L, 2017. UV-straling en gezondheid: Probleemveld en kennisbasis bij het RIVM. Rijksinstituut voor Volksgezondheid en Milieu RIVM. Available online: http://hdl.handle.net/10029/620876

Slaper H, Velders GJ, Daniel JS, de Gruijl FR & van der Leun JC, 1996. Estimates of ozone depletion and skin cancer incidence to examine the Vienna Convention achievements. Nature, 384 (6606), 256-258. Available online: https://doi.org/10.1038/384256a0

World Health Organization ICoN-IRP, 2002. Global solar UV index: a practical guide. 9241590076. World Health Organization.

Zou W, Ramanathan R, Urban S, Sinclair C, King K, Tinker R & Bansal V, 2022. Sunscreen testing: A critical perspective and future roadmap. TrAC Trends in Analytical Chemistry, 157, 116724. Available online: https://doi.org/https://doi.org/10.1016/j.trac.2022.116724

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Abbreviations

BCC	Basal cell carcinoma
BuRO	Office for Risk Assessment & Research
FDA	Food and Drug Administration
HDRS	Hybrid Diffuse Reflectance Spectroscopy
ISO	International Organisation of Standardisation
ITA	Individual Typology Angle
MED	Minimum Erythemal Dose
MPPDD	Minimal Persistent Pigment Darkening Dose
NVWA	Netherlands Food and Consumer Product Safety Authority
SCC	Squamous cell carcinoma
PMMA	Polymethyl methacrylate
PDD	Persistent Pigment Darkening
ROS	Reactive Oxygen Species, oxygen radicals
SCCS	Scientific Committee on Consumer Safety
SED	Standard Erythemal Dose
SPF	Sun Protection Factor
UPF	Ultraviolet Protection Factor
UV	Ultraviolet
UVA-PF	UVA Protection Factor

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Annex 1: Literature study

Table 3: Literature search terms

Search terms	Date	Location
SPF AND protection AND health AND risk	March 2023	Scopus
sunscreen AND uv AND health AND risk	March 2023	Scopus
"sun protection factor" "health risk"	March 2023	Scopus
Sunscreen and prevention of cancer	March 2023	Google
Anti-inflammatory UV-filters sunscreen	September 2023	Pubmed
Sunscreen testing	September 2023	Pubmed
Testing technology safety sunscreen	September 2023	Pubmed
Photo-instability UV-filters	October 2023	Pubmed

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Annex 2: Results of the NVWA study

In the NVWA study of 2023, 54 sunscreen products were sampled, with a claimed SPF of 30 or higher. For these samples, the SPF (UVB protection) and the UVA-PF were determined using the *in vitro* double plate method. For a number of samples, an *in vivo* SPF determination was also conducted by an external laboratory. Moreover, the concentrations of UV filters in these samples were determined, and an in silico calculation was carried out. In the double plate method, an additional irradiation step was included to measure the efficacy of the sunscreen products following exposure to UV radiation.

In Table 8, the red figures indicate instances where the measured *in vitro* SPF (following irradiation) is lower than the claimed SPF. If the ratio between UVA and UVB protection, determined using the double plate *in vitro* method, is lower than 33% (one third), this is also marked red. Table 8 gives the following measurement results for each sample:

- SPF label: The UVB protection factor stated on the label of the sunscreen product.
- *In vitro* SPF prior to irradiation. The initial SPF (UVB protection) determined by the NVWA laboratory using the double plate method.
- *In vitro* SPF following irradiation. The SPF (UVB protection) after the plate with the sunscreen product is exposed to maximum irradiation with UV light.
- UVA-PF: The UVA protection factor determined using the double plate *in vitro* method (same measurement as UVB *in vitro).*
- UVA/UVA ratio (%): The ratio between UVA and UVB protection of the sunscreen product measured using the double plate *in vitro* method.
- *In vivo* SPF: UVB protection measured using the *in vivo* reference method ISO 24444.
- In silico SPF: UVB protection calculated on the basis of the UV filter levels measured.

Table 4: Results of NVWA study of the SPF of sunscreen products 2023

Sample number	SPF Label	SPF *in vitro* prior to irradiation	SPF *in vitro* following irradiation	UVA-PF	UVA/UVB ratio (%)	SPF *in vivo*	SPF in silico
87101223	50	58.5	27.4	12.7	46.4	64.5	37
87101231	50+	40.7	34.1	22.5	66.0		29
87101258	50+	74.2	53.0	26.6	50.2		39
87101266	30	34.7	32.6	19.0	58.3		28
87101282	30	33.8	33.2	14.9	44.9		35
87101304	50	77.9	88.4	47.4	53.6		56
87420132	50+	71.1	48.5	24.2	49.9		39
87420159	50	34.4	26.4	16.9	64.0		30
87420167	50+	79.9	60.0	39.1	65.2		39
87420175	30	32.3	20.7	6.8	32.9		25
87360083	30	22.1	20.6	14.4	69.9	42.6	28
87360105	30	54.7	47.6	29.9	62.8		29
87360113	30	43.7	29.5	14.6	49.5		34
87360075	30	11.1	10.9	7.2	66.1		15
87360091	50	54.3	48.3	24.3	50.3		35
87360148	50	7.7	7.6	6.6	86.8	15.4	16
87360121	50	127.5	83.0	37.7	45.4		41
87360156	50	7.3	7.2	6.4	88.9	44.8	15
87173682	30	10.9	8.0	2.7	33.8	20.8	16
87173747	30	30.6	25.7	13.7	53.3		16
87173763	30	33.3	29.0	18.0	62.1		28
87173704	30	18.9	16.5	11.6	70.3	42.3	29

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Sample number	SPF Label	SPF *in vitro* prior to irradiation	SPF *in vitro* following irradiation	UVA-PF	UVA/UVB ratio (%)	SPF *in vivo*	SPF in silico
87173771	50	70.2	71.3	26.5	37.2		39
87173712	50	14.6	15.0	10.0	66.7		31
87173755	50	16.9	13.4	12.3	91.8		33
87420183	50	50.1	45.9	27.0	58.8		28
87173828	30	9.3	9.2	6.8	73.9	26.4	14
87173836	30	29.0	23.8	8.1	34.0		27
87420205	50	61.4	62.4	29.6	47.4		36
87420213	50	24.5	13.5	2.9	21.5	45.8	28
87420221	50+	62.2	46.2	15.2	32.9		36
87420248	50+	43.4	39.2	24.3	62.0		28
87360369	50+	3.5	3.2	1.5	46.9	10.2	5
87360377	50	52.6	57.1	23.6	41.3		25
87101371	30	22.1	19.1	20.7	108.4		19
87101401	50+	48.0	39.7	21.6	54.4		25
87101428	50+	9.7	10.2	8.2	80.4		16
87101398	50+	74.3	73.2	63.5	86.7		33
87420361	50	61.3	27.8	11.1	39.9		31
87173887	30	37.4	40.2	23.9	59.5		28
87173895	30	56.6	50.6	27.2	53.8		38
87173879	50	47.5	46.7	14.2	30.4		32
87173852	50	89.5	69.7	23.0	33.0		50
87173909	50+	95.8	84.3	23.6	28.0		63
87377695	30	20.0	19.2	11.0	57.3	38.6	15
87377709	30+	1.7	1.7	1.5	88.2	5.7	3
87420388	50+	26.7	29.8	11.3	37.9		25
87360415	30	21.8	21.4	12.5	58.4		19
87420434	50+	75.7	58.3	26.8	46.0	61.4	39
87422119	30	68.1	71.1	69.9	98.3		36
87422127	50+	83.3	77.4	67.1	86.7		36
87173917	30	6.4	6.0	5.1	85.0	14.8	13
87422216	30	9.1	8.6	6.4	74.4		15
87101533	50+	23.4	22.2	10.5	47.3		20