HDRS - ISO 23698

Hybrid Diffuse Reflectance Spectroscopy

Mathias Rohr

Measurement of the sunscreen efficacy
by diffuse reflectance spectroscopy

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ISO 23698
HDRS (Hybrid Diffuse Reflectance Spectroscopy)

- Basic Ideas of HDRS
- Technique
- Important Side Parameter
- Photostability

- Basic Ideas of HDRS

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From DRS to HDRS / From UVA-PF to SPF

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A view into History

1997 Gillies R, Kollias N, Noninvasive in vivo determination of sunscreen ultraviolet A factors usinf diffuse reflectance spectroscopy. In: Lowe N, Shaath N, Pathak N, eds, Sunscreens: development, evaluation and regulatory aspects. New York, NY: Marcel Dekker Inc., 1997;601-603

2003 Gillies R, Moyal D, Ferestier S, Kollias N, Non-Invasive in vivo deter *Photodermatol Photoimmunol Photomed*. 2003; 19:190–194

2009 Ruvolo E, Chu M, Grossman F, Cole C, Kollias N, Diffuse reflectance between in vitro and in vivo measurements *Photodermatol Photoi*

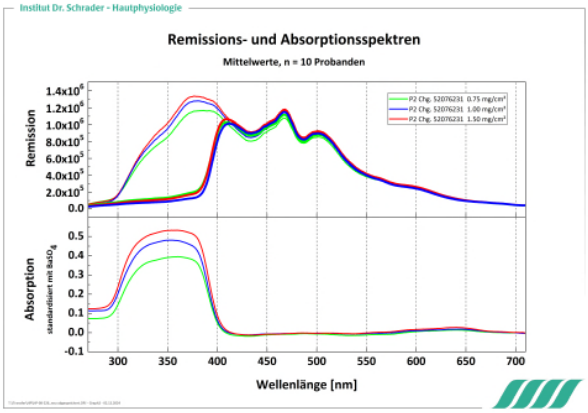
2014 Ruvolo E, Kollias N, Cole C. New non-invasive approach assessing i vitro transmission. *Photoderm Photoimmun Photomed*. 2014;30(4

2018 Rohr M, Ernst N, Schrader A. Hybrid diffuse reflectance spectrosc *Physiol*. 2018;31:220-228.

2020 Ruvolo E, Aeschliman L, Cole C. Evaluation of sunscreen efficacy o *Photodermatol Photoimmunol Photomed*. 2020;00:1–8

2021 Rohr M, Schrader A. HDRS – Hybrid Diffuse Reflectance Spectrosc U (eds): Challenges in Sun Protection. Curr Probl Dermatol. Basel,

2021 Ruvolo E, Rohr M, Oliveira S, Nogueira L, Carvalho J, Cole C. Multi- SPF and UVA-PFs. *Photodermatol Photoimmunol Photomed*. 2021;



From DRS to HDRS / From UVA-PF to SPF

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A successful end of a long journey

Published December 2024

Scope of ISO 23698

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Characterization of:

- Sun Protection Factor (SPF)
- UVA Protection Factor (UVA-PF)
- Critical Wavelength (CW)

} of sunscreen products without requiring biological response

Applicable for:

- Emulsions
- Single-Phase Products (alcoholic one-phase formulation, oil and sticks)
- Products that contain any component able to absorb, reflect or scatter UV rays

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UVA-PF / SPF – Classic Approach

ISO 24442 / ISO 24444

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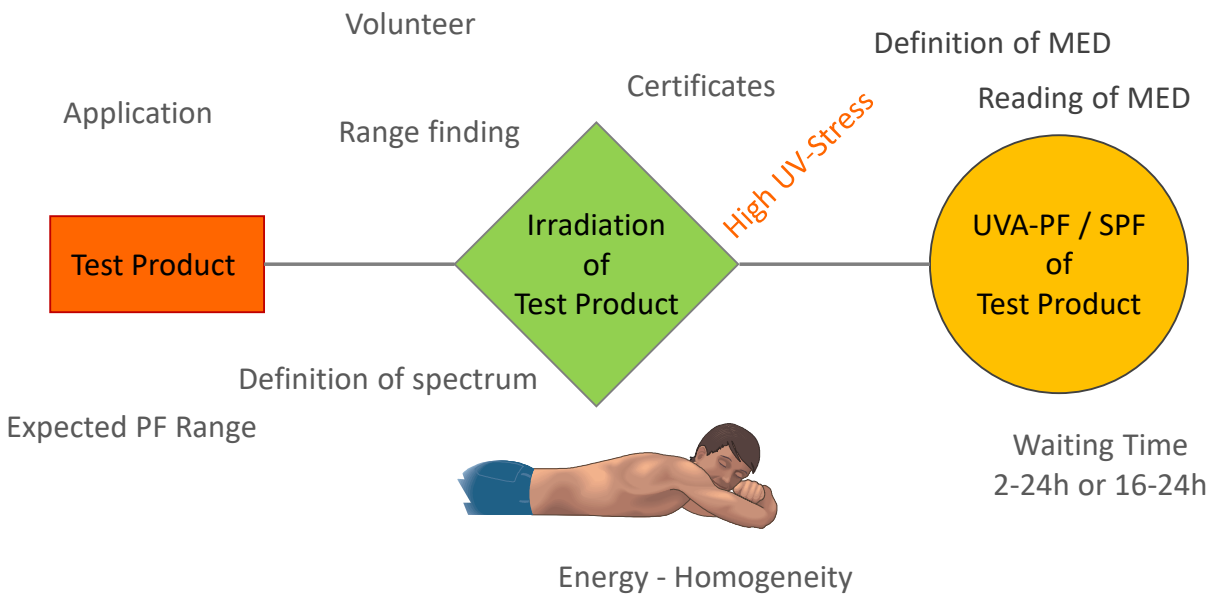

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UVA-PF / SPF – Quantification

ISO 24442 / ISO 24444

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UVA-PF

Identification of MPPDD
Ratio of Doses
Calculation of UVA-PF

SPF

Identification of MED
Ratio of Doses
Calculation of SPF

In both cases a high UV-dose is needed
Ethical Concerns!

In order to get rid of this HDR Not to lose interaction with skin

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Light and Skin - What happens?

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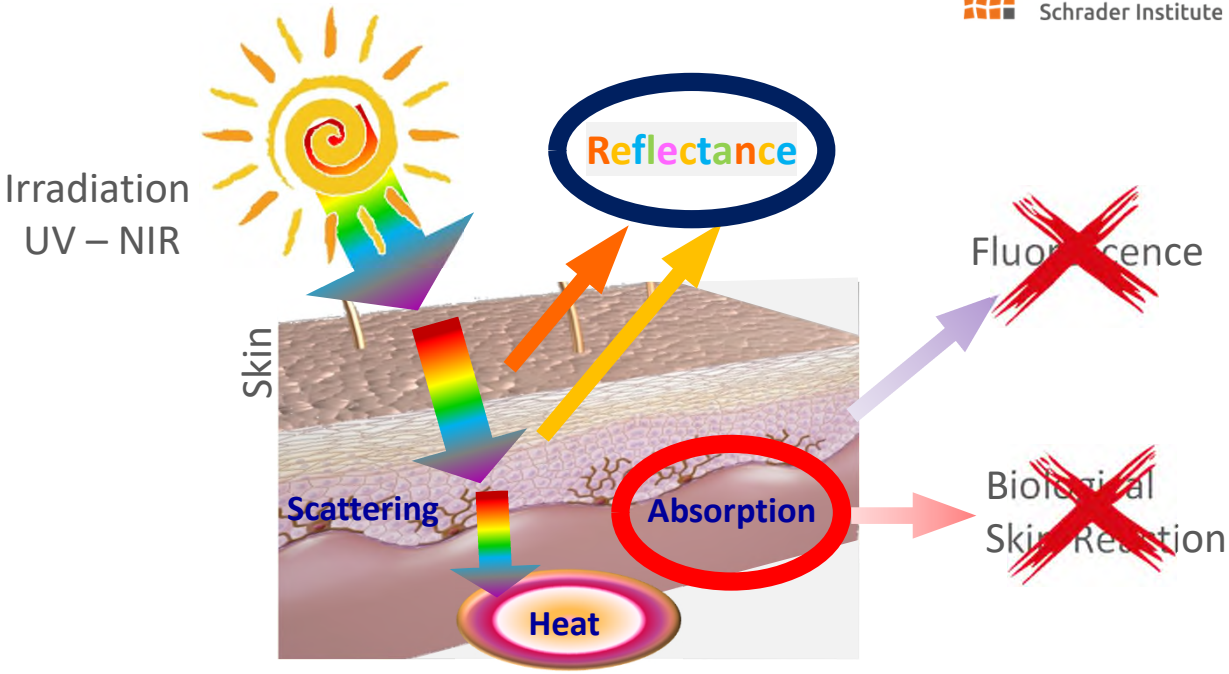

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HDRS – 1 Experiment / 2 Results: UVA-PF and SPF

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UVA-PF

$$UVA\text{-}PF_{HDRS} = \frac{\int_{\lambda=320}^{\lambda=400} P(\lambda)\, I(\lambda)\, d\lambda}{\int_{\lambda=320}^{\lambda=400} P(\lambda)\, I(\lambda)\, 10^{-A(\lambda)}\, d\lambda}$$

P(λ) = PPD Action Spectrum
I(λ) = Spectral Irradiance (UVA)
A(λ) = Absorbance

SPF

$$SPF_{HDRS} = \frac{\int_{\lambda=290}^{\lambda=400} E(\lambda)\, I(\lambda)\, d\lambda}{\int_{\lambda=290}^{\lambda=400} E(\lambda)\, I(\lambda)\, 10^{-A(\lambda)}\, d\lambda}$$

E(λ) = Erythemal Action Spectrum
I(λ) = Spectral Irradiance
A(λ) = Absorbance

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ISO 23698
HDRS (Hybrid Diffuse Reflectance Spectroscopy)

- Technique
- Important Side Parameter
- Photostability

- Technique
- Important Side Parameter
- Photostability

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HDRS – Technique

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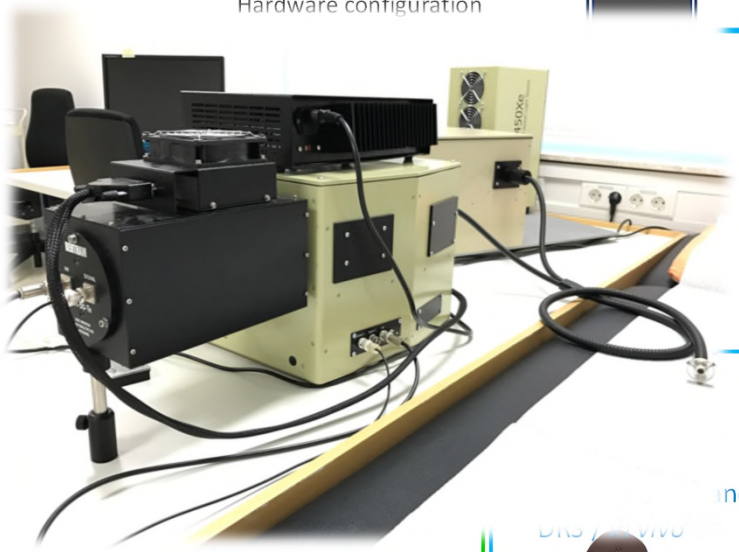
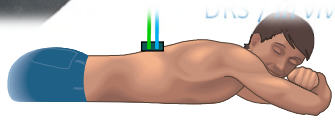
Hardware configuration



Signal analysis

UVB / UVA
Detection

Emission
monochromator



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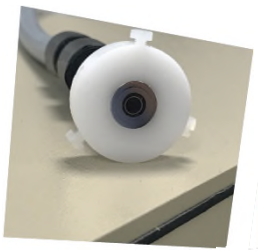
HDRS – Technique



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DRS – Spectrum from skin with Sunscreen

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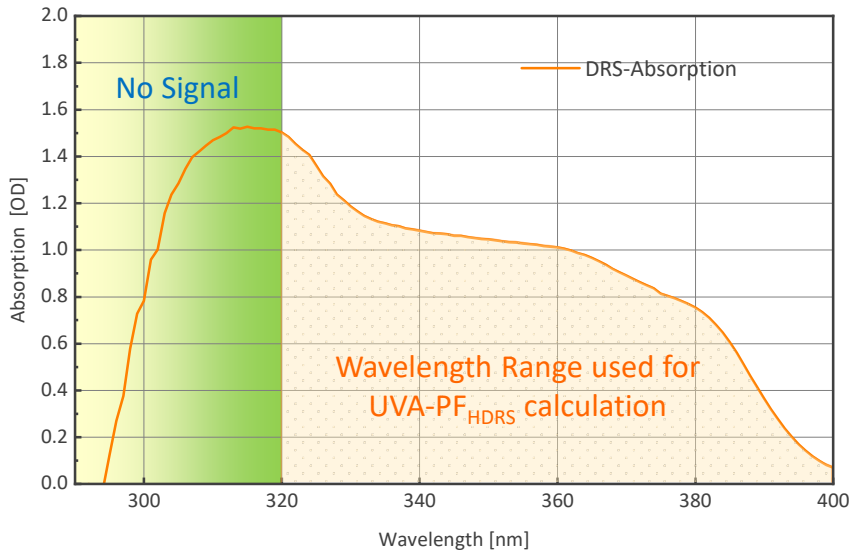

$$T_{DRS} = \sqrt{\frac{R_p(\lambda)}{R_u(\lambda)}}$$

$$A_{DRS} = -\log T_{DRS}(\lambda)$$

R(λ) : Remission Signal
T(λ) : Transmission
A(λ) : Absorbance

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HDRS – From DRS to HDRS

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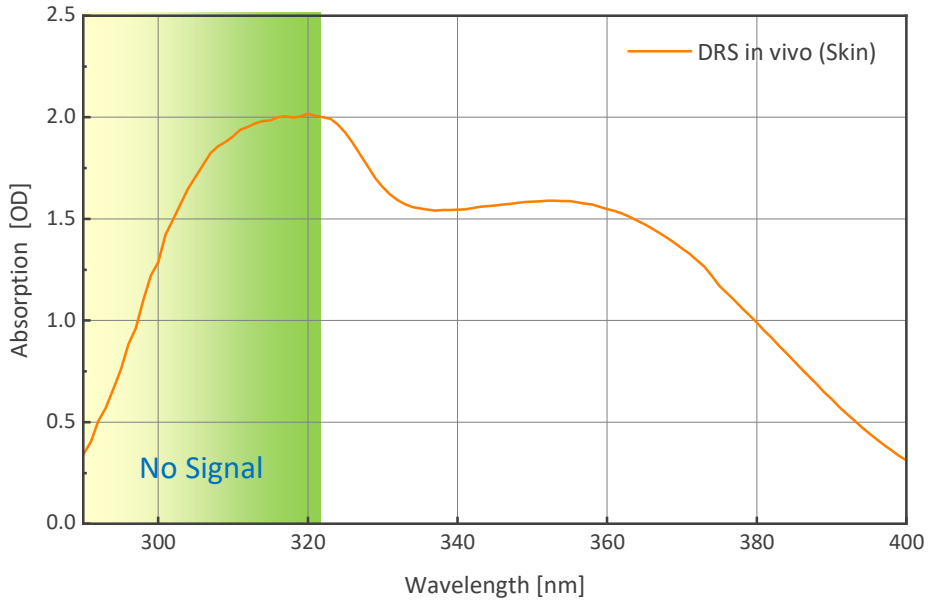
Replacement of the non measurable UVB-part

by data from an *in vitro* transmission measurement on PMMA plates

adjusted to the *in vivo* amplitude of DRS



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SPF_{HDRS} – Technique

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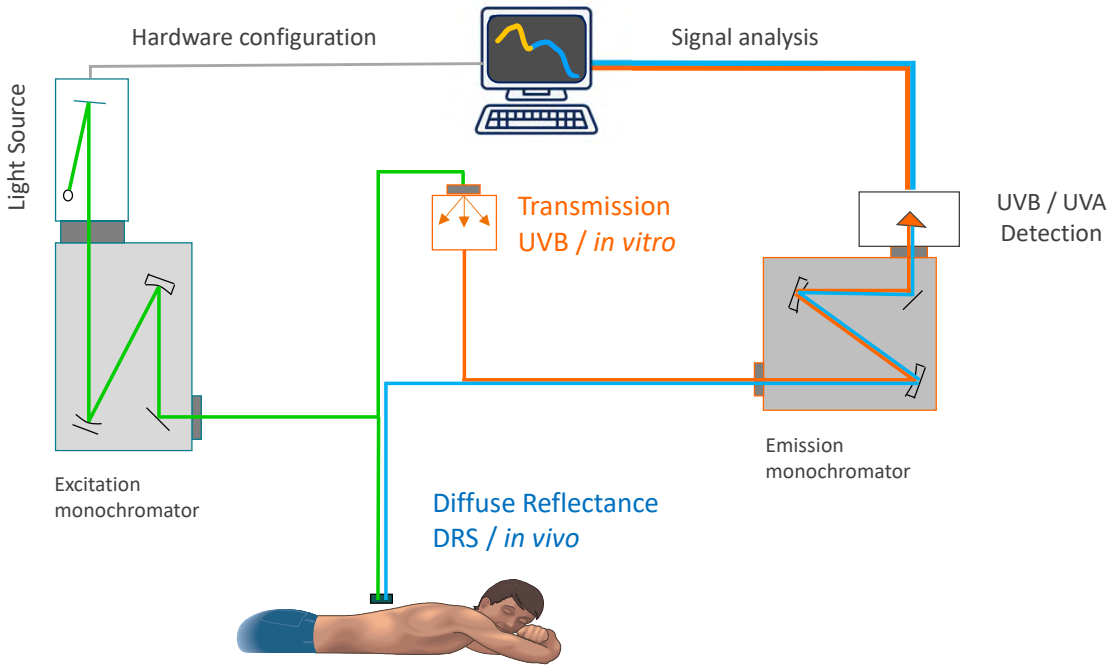

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HDRS – The *in vitro* part

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SPF_{HDRS} – Hybrid-Signals

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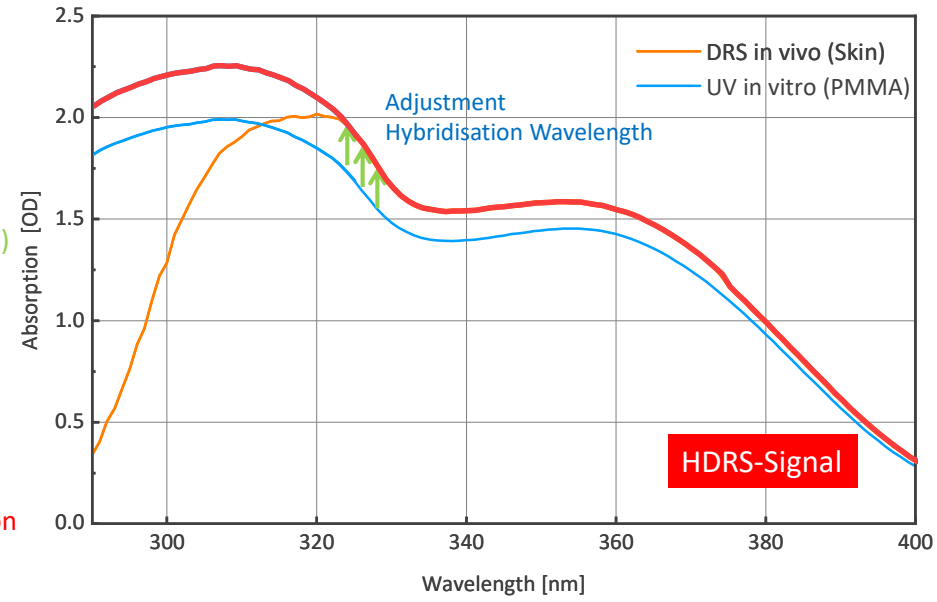
- *in vitro* measurement
- identification of Hybridisation Wavelength (HW)
- shift of *in vitro* part to *in vivo* DRS-level
- HDRS-Spectrum for SPF calculation



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HDRS – 1 Experiment / 2 Results: UVA-PF and SPF

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UVA-PF

$$UVA\text{-}PF_{HDRS} = \frac{\int_{\lambda=320}^{\lambda=400} P(\lambda)\, I(\lambda)\, d\lambda}{\int_{\lambda=320}^{\lambda=400} P(\lambda)\, I(\lambda)\, 10^{-A(\lambda)}\, d\lambda}$$

$-A(\lambda)$ → DRS(λ)

Pure *in vivo* data

SPF

$$SPF_{HDRS} = \frac{\int_{\lambda=290}^{\lambda=400} E(\lambda)\, I(\lambda)\, d\lambda}{\int_{\lambda=290}^{\lambda=400} E(\lambda)\, I(\lambda)\, 10^{-A(\lambda)}\, d\lambda}$$

$-A(\lambda)$ → DRS(λ) + *in vitro* absorption

Combination of *in vivo* and *in vitro* data

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ISO 23698
HDRS (Hybrid Diffuse Reflectance Spectroscopy)

- Important Side Parameter
  - Photostability
  - Photostability
- Important Side Parameter

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ISO 23698 - Parameter

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Product-
Application

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Product Application

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- Product: 2.00 mg/cm² +/- 2.5% (0.05 mg/cm²)
- Product Distribution: 20 – 50s
- Balance: in min. 0.1 mg
- Waiting Time: in min. 15 min
- Test Area: Back 30 – 60 cm²
  min. 1 cm Distance

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Product Application – Method

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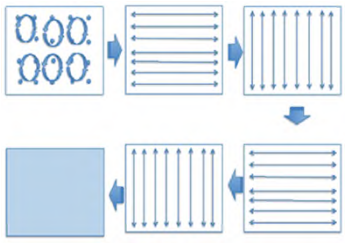
- 3 Application Methods
- Method A: Lotion – Cream – Oil – Liquid – Gel – Pump Spray – Roll on Aerosol Spray (Degassing for 24h)
- Method B: Stick – Balm – Roll on
- Method C: Foaming Formulation



Method A

- Droplets
- Syringe/Pipette
- Sprays are degassed 24h

Method B

- Weighing boat
- distribution by finger

Method C

- Weighing boat
- Degassing
- Method B

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ISO 23698 - Parameter

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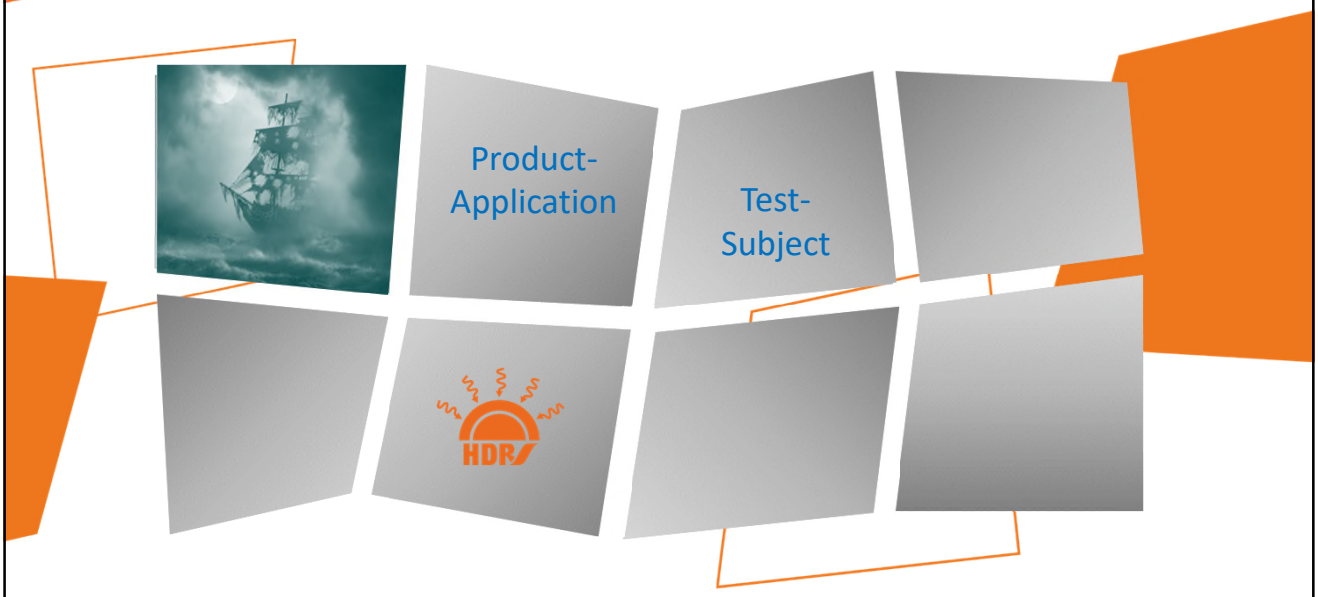

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Test Subject

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- Subject exclusion criteria

  Children or person below the locally legal age of consent
  Systematic dermatological conditions
  Excessive hair in the test area
  UV-exposures within the past 8 weeks

- Test Panel: ITA° ≥ 28 and an average between 41° - 55°

ITA° ≥ 56°	very light	1 of each group	or 3 out of 2 groups
ITA° 41° - 55°	light		
ITA° 28° - 40°	intermediate		

ITA° = [arc tg ((L*-50)/b*)] 180 / 3.1416

(ITA° : Individual Typology Angle)

- Test Panel: Full-Test n=10 combined with a 95%-CI < 17% for SPF and UVA-PF

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ISO 23698 - Parameter

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Product-Application

Test-Subject

Technical Equipment

HDR

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Technical Equipment

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- Monochromatic or Polychromatic
- Maximum exposure dose of 10 J/m^2 (MEDu $\approx 210\ J/m^2$)
- Maximum exposure irradiance at skin surface < 5 mW/cm^2
- Linear response detection shall be at least 5 decades (6 decades are recommended) in the range 290-400 nm
- Monochromator - Wavelength accuracy of +/- 0.1 nm (monoHDRS)
- PMT detector system similar to PPD action spectrum (polyHDRS)

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ISO 23698 - Parameter

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Product-Application

Test-Subject

Technical Equipment

Training for Technician

HDR

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Training of Technician

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- For the first time a Training of Technicians is part of an ISO-Method
- Based on HDRS generated UVA-PF values
- Measured within a test area of 4 products:
  - P5 or P8
  - S2
  - Alcoholic single phase product
  - Product with high inorganic UV filters (at least 20%)
- Uniform spreading shall be demonstrated by a c val out of 9 measurements

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ISO 23698 - Parameter

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Product-Application

Test-Subject

Technical Equipment

Training for Technician

HDR

Statistic of Results

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Dose Increments – SPF ISO 24444

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SPF	30	Untreated					
Progression	1.12	0.71	0.80	0.89	1.00	1.12	1.25
Protected	0.71	30	27	24	21	19	17
	0.80	34	30	27	24	21	19
	0.89	38	34	30	27	24	21
	1.00	42	38	34	30	27	24
	1.12	47	42	38	34	30	27
	1.25	53	47	42	38	34	30

- ISO 24444
  An SPF-Test can only generate discrete SPF-values

- ISO 23698
  No longer applicable
  Any value is possible

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HDRS – Results - ISO 23698

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- ISO 23698 - No expected SPF needed
- ISO 23698 - No irradiation - In consequence no Dose-Progression
- ISO 23698 - Results are not limited to certain values
- ISO 23698 - Results are log-normal distributed (slightly different mathematics)

Statistic – Geometric Mean (ISO 23698)

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- SPF_{HDRS} and UVA-PF_{HDRS} are the Geometric Mean of at least 10 subjects (i) and 20 subjects in maximum

$$SPF_{HDRS} = \exp\left[\frac{\sum_{i=1}^{n}\ln(SPF_{HDRSi})}{n}\right] \qquad UVA-PF_{HDRS} = \exp\left[\frac{\sum_{i=1}^{n}\ln(UVA-PF_{HDRSi})}{n}\right]$$

- The c-value (95%-CI) shall be ≤ 0.17 for SPF_{HDRS} and UVA-PF_{HDRS}

$$c = \left[\frac{t_{(0,05,n-1)} \times (\sigma)}{\sqrt{n}}\right] \leq 0,17$$

ISO 23698 - Parameter

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Product-Application

Test-Subject

Technical Equipment

Training for Technician

HDR

Statistic of Results

Standard Products

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Reference Sunscreen Formulations

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Reference Sunscreen	Mean SPF	Acceptance Limits Lower Limit	Acceptance Limits Upper Limit	Mean UVA-PF	Acceptance Limits Lower Limit	Acceptance Limits Upper Limit	CW Lower Limit	CW Upper Limit
P5	30.6	23.7	37.4	13.4	11.3	15.3	373 nm	379 nm
P6	43.0	31.0	54.9					
P8	63.1	43.9	82.3	27.5	23.4	31.7	378 nm	381 nm
S2				12.7	10.7	14.3	378 nm	382 nm

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ISO 23698
HDRS (Hybrid Diffuse Reflectance Spectroscopy)

- Photostability
- Summary

- Photostability

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HDRS – Photostability

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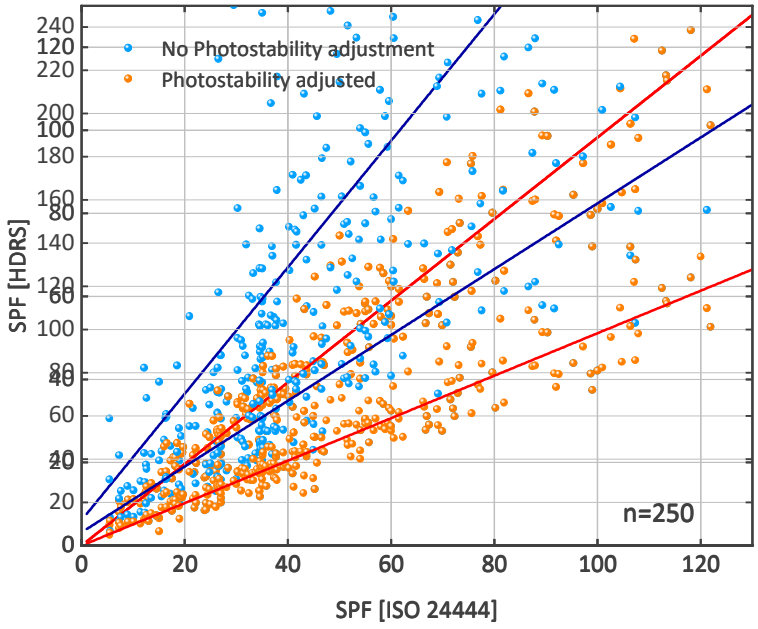

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How can we handle this?

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HDRS – Photostability

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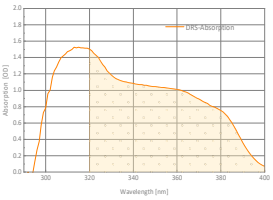
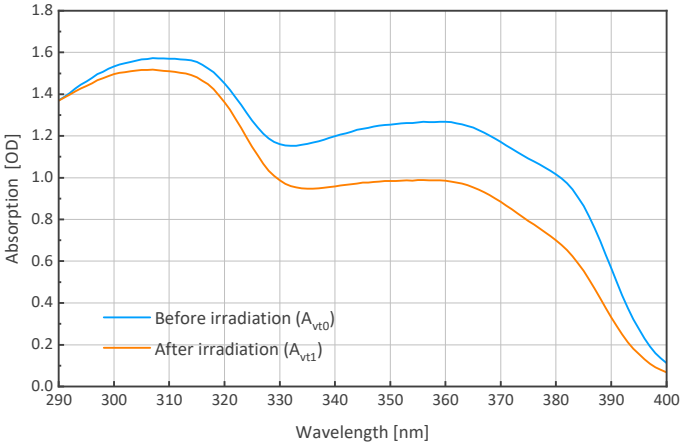
Basic Idea: Follow ISO 24443 / Spectrum ISO 24444

Dose calculation based on UVA-PF_{DRS}



DRS-Signal



$D = 1.2 \times UVA\text{-}PF_{DRS}$

$$Ratio(\lambda) = \left[\frac{A_{vt1}(\lambda)}{A_{vt0}(\lambda)}\right]$$

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HDRS – Photostability / 10^A

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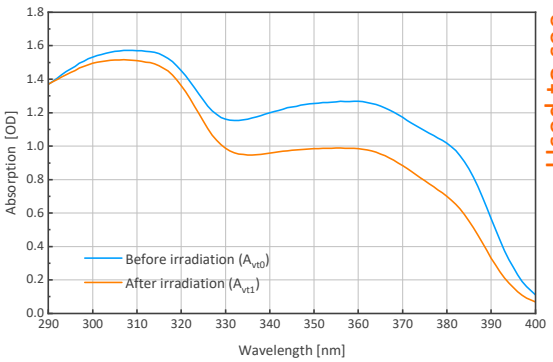
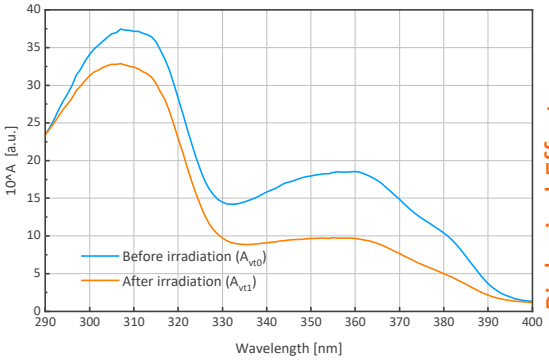


Used to see

$$SPF_{HDRS} = \frac{\int_{\lambda=290}^{\lambda=400} E(\lambda)\, I(\lambda)\, d\lambda}{\int_{\lambda=290}^{\lambda=400} E(\lambda)\, I(\lambda)\, 10^{-A(\lambda)}\, d\lambda}$$

$$Ratio(\lambda) = \left[\frac{A_{vt1}(\lambda)}{A_{vt0}(\lambda)}\right]$$

Unfortunately we did not succeed with this approach!



Biological Effect to be handled

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HDRS – Photostability / SRPD

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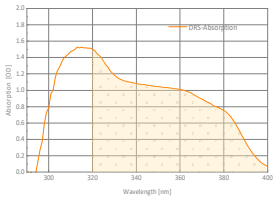
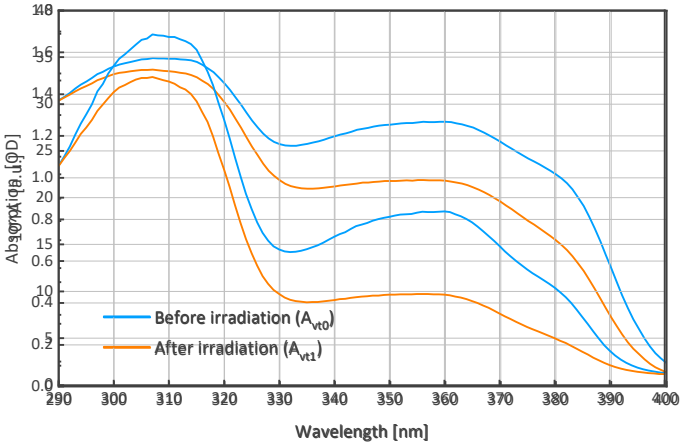
Basic Idea: Follow ISO 24443 / Spectrum ISO 24444

Dose calculation based on UVA-PF_{DRS}



DRS-Signal



$D = 1.2 \times UVA\text{-}PF_{DRS}$

$$SRPD(\lambda) = \frac{10^{A_{vt1}}(\lambda)}{10^{A_{vt0}}(\lambda)}$$

Spectral Ratio of Photo-Degradation

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HDRS – Photostability -SRPD

Spectral Ratio of Photo-Degradation

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For most of the products this is the best adjustment of Photo-Degradation we found

Unfortunately still not for ALL

$$SRPD_{UVB} = \frac{\sum_{\lambda 1}^{\lambda 2}(10^{A_{vt1}}(\lambda)/10^{A_{vt0}}(\lambda))}{31}$$

$$SRPD_{UVA} = \frac{\sum_{\lambda 2}^{\lambda 3}(10^{A_{vt1}}(\lambda)/10^{A_{vt0}}(\lambda))}{81}$$

$$SRPD_{mean} = (SRPD_{UVA} + SRPD_{UVB})/2$$

λ1 = 290 nm
λ2 = 320 nm
λ3 = 400 nm

dλ = 1 nm

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HDRS – Photostability / SRPD

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Procedure	SRPD (λ) Determination
If the lowest value of $SRPD_{UVB}$ or $SRPD_{mean}$ is ≥ 0.8	$SRPD(\lambda) = \frac{10^{A_{vt1}(\lambda)}}{10^{A_{vt0}(\lambda)}}$ where any individual SRPD (λ) ≥ 1.0 then the SRPD(λ)=1.0
If the lowest value of $SRPD_{UVB}$ or $SRPD_{mean}$ is < 0.8 but ≥ 0.7	$SRPD(\lambda) = \left[\frac{10^{A_{vt1}(\lambda)}}{10^{A_{vt0}(\lambda)}} + \frac{A_{vt1}(\lambda)}{A_{vt0}(\lambda)}\right]/2$ where any individual SRPD (λ) ≥ 1.0 then the SRPD(λ)=1.0
If the lowest value of $SRPD_{UVB}$ or $SRPD_{mean}$ is < 0.7	$SRPD(\lambda) = \left[\frac{A_{vt1}(\lambda)}{A_{vt0}(\lambda)}\right]$ where any individual SRPD (λ) ≥ 1.0 then the SRPD(λ)=1.0

HDRS – Photostability / SRPD

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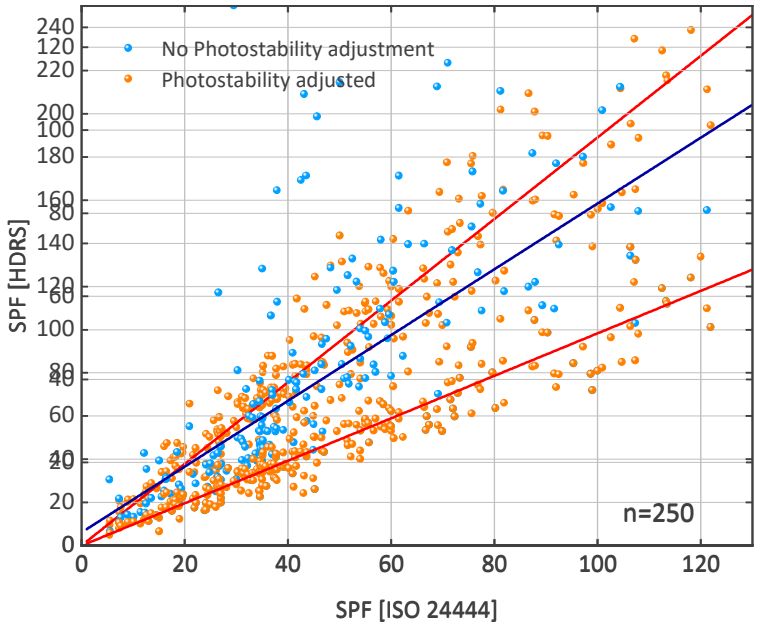

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How can we handle this?

by SRPD(λ)

HDRS – Photostability / SRPD-Distribution

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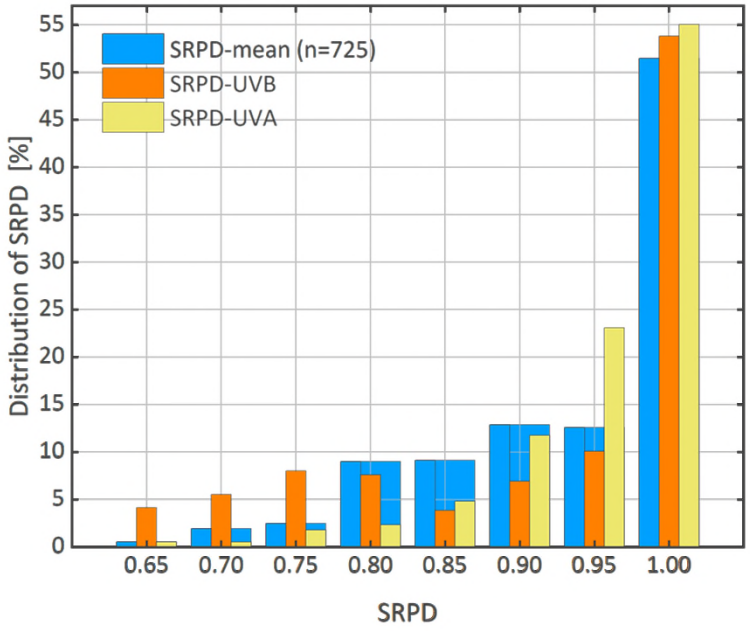

- About 65% are in the highest stability class $SRPD_{mean} > 0.9$
- About 84% are in Category 1
  About 13% are in Category 2
  About 3% are in Category 3

Photosability
Key-Factor for HDRS
Handled by SRPD(λ)

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ISO 23698
HDRS (Hybrid Diffuse Reflectance Spectroscopy)

- Summary

- Summary

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SPF ISO 23698 – What is needed?

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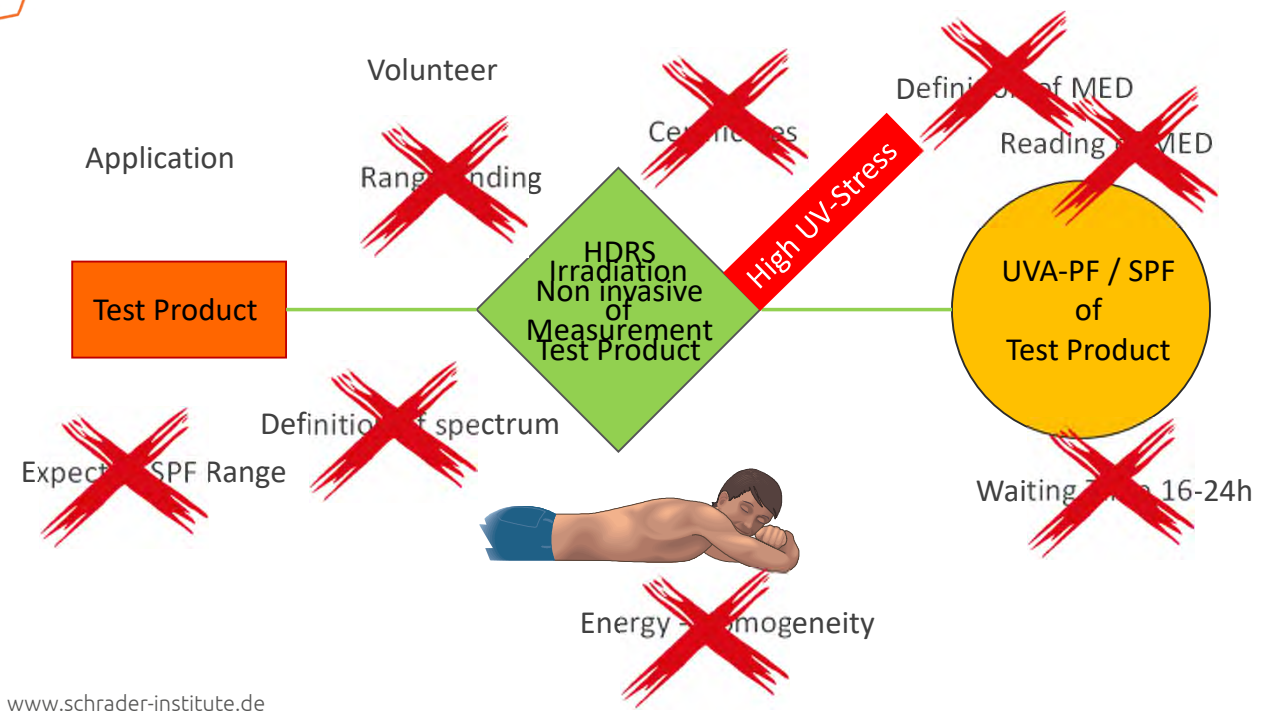

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HDRS – ISO 23698:2024
The NEW alternative SPF and UVA-PF – *in vivo*

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Not needed:

- Harmful UV radiation
- Expected SPF
- MED definition and reading
- Longer test time for higher SPF
- Separate testing of SPF, UVA-PF, CW

Advantage:

- Still *in vivo* but no Ethical Concerns
- Correlation of: SPF_{24444} and SPF_{HDRS}; $UVA\text{-}PF_{24443}$ and $UVA\text{-}PF_{HDRS}$; $UVA\text{-}PF_{24442}$ and $UVA\text{-}PF_{HDRS}$
- No Limits: Level of SPF; Level of UVA-PF; Type of formulation; Type of UV-Filter
- Photostability included
- Water-Resistance Testing included

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HDRS – ISO 23698

By the way

ISO 23698

→ Final release December 2024

Victor Hugo (1802-1885)

Nothing is stronger than an idea whose times has come!

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Headquarters - Holzminden

Normec Schrader Institute

Vielen Dank für Ihre Aufmerksamkeit

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Many thanks
for your kind attention

Normec
Schrader Institute

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