

European UV Sunfilters

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CONFERENCE PROCEEDINGS

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IN-VIVO STUDIES OF UV EFFECTS IN HUMAN SKIN USING PHOTOACOUSTICS

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1. Introduction

For several medically interesting molecular gases the detection limits offered by photoacoustic spectroscopy are orders of magnitude better than for commonly used detectors (down to 6 ppt; i.e. 6 particles out of 10^{12} using an intracavity CO₂ laser setup).

This opens new perspectives for on-line experiments to study dynamical changes in physiological processes, which may provide a non-invasive diagnostic means for medical use. Molecules that are created somewhere in the body due to certain processes in the body, or in the skin, may be transported by the blood to the lungs, and hence enter the breath.

One of the physiological processes that is of interest in medicine is lipid peroxidation, i.e. cell membrane damage. This damage is mostly caused by free radicals, which can e.g. be formed under the influence of UV-radiation [1]. Some end products of this process are ethane, pentane and ethene [2], molecules that can be measured very sensitively using photoacoustic detection. This therefore provides a means to determine the degree of lipid peroxidation.

To investigate the effect of UV-radiation on human skin *in vivo*, two types of experiment were conducted: 1) measuring the ethene emitted directly by small patches of skin exposed to UV light; 2) measuring the ethene level in exhaled air from humans during whole-body exposure to UV light. Commercial sunbeds were used as UV sources.

2. Experiments

2.1 Photoacoustics

In photoacoustic spectroscopy the absorption spectra of molecular gases is used to detect very small quantities of these gases [3]. Different molecules show a distinctly different absorption of light at different wavelengths. Thus it is possible to distinguish between different molecules based on their fingerprint-like absorption spectrum.

In photoacoustic spectroscopy a gas is put in a confined space (the photoacoustic cell) through which light is sent at a specific wavelength. Specific molecules in the gas absorb the photons. The absorbed photon energy is transformed into translation energy by collisions, resulting in a rise in gas-temperature. Due to the confined space, the temperature-rise causes an increase in pressure. Switching the light on and off at an acoustic frequency results in an alternating pressure rise and fall, i.e. an acoustic wave in the photoacoustic cell. This acoustic signal is

directly related to the concentration of absorbing molecules in the cell. Using a sensitive microphone to measure this signal, very low concentrations can be detected. When the absorption coefficients of possibly present gases at different wavelengths are known, different trace gases can be distinguished by measuring the photoacoustic signal at a number of wavelengths.

2.2 Experimental Set-Up

The effect of UV radiation on human skin is measured in two ways: via the ethene that is emitted directly by the skin and via the ethene that enters the body and is then emitted via the breath.

To measure the ethene emitted by the skin, a sampling cell consisting of a metal ring with a quartz glass window on one side is put on the skin, thus producing a closed space, where the skin forms the bottom of the chamber. Clean air from a compressed air bottle is sent into the chamber via a small hole on one side of the ring, and leaves the chamber via a similar hole on the opposite side, taking the ethene emitted by the covered portion of the skin with it. The quartz window allows UV light, UV-A as well as UV-B, to reach the skin. The diameter of the chamber is 5 cm, thus making measurements of relatively small skin areas possible. This allows measurements to be taken on the same type of skin (e.g. inside of arm) under different conditions (e.g. using different UV wavelengths) on the same day.

To detect the ethene that leaves the skin via the body, the ethene level present in exhaled air is measured. For this, clean, compressed air from a bottle is used to fill a 60 liter aluminized bag from which test persons can breath comfortably via a wide tube and a two-way breathing valve fitted to a face-mask. The valve directs the air that is exhaled into a second wide tube, where the pulmonary volume is measured using a spirometer. This is needed to determine the dilution rate of the measured gas, as a higher breath volume implies a lower concentration at the same ethene concentration in the lungs. Most of the exhaled breath enters the outside air, but a small portion (3 l/h) is sucked out and directed to the photoacoustic set-up to determine the ethene concentration. This portion is sucked up as closely as possible to the face mask, so that most of this air comes from the alveolar part of the lungs, where the air-exchange with the blood takes place.

Before the sampled air from either the skin or the breath reaches the photoacoustic cell, it is sent through chemical scrubbers and a cooling trap to take out molecules that may interfere with ethene spectroscopically (e.g. water, CO₂, and acetone). As breath contains much water, prior to this the exhaled air is first directed through Nafion tubing to prevent condensation.

The photoacoustic detector consists of a CO₂-laser with an intra-cavity placed photoacoustic cell. The wavelengths generated by this type of laser allow very sensitive detection of ethene (down to 6 ppt, i.e. 6 particles out of 10¹⁰).

In the experiments presented here, two commercially available UV sources are used. The skin experiments, where only a circular area of 5 cm diameter is irradiated, were done using a Philips HB 8/2 solarium, containing three 400 W Cleo lamps. For the breath analysis, where the whole body, apart from the head, is irradiated, a Dr. Müller sunbed (Combi 12/12) containing three types of lamps is used.

3. Results

3.1.1. skin measurements

The skin measurement cell was put on the inside part of an arm of a volunteer. For the first 15 minutes, the base level of ethene emission from the volunteer's skin is measured. Then the UV source is switched on for a fixed time (generally 10 or 15 minutes). After the light source has been switched off, the measurement continues for another 15 minutes, to measure the emission after the exposure. The measurements show that the ethene emission rises immediately after starting the UV irradiation and decreases again immediately after the light source is switched off (see for example Figs. 2 and 3). It was found that measurements taken on similar parts of either arm of the same person result in the same amount of ethene being emitted. Thus, different radiation-conditions can be studied by exposing each arm differently on one person.

To study the effect of the UV intensity on the amount of ethene that is emitted, the irradiation intensity is adjusted by changing the distance between the exposed skin and the UV-source. For a Philips HB8/2 solarium, having three IPA 400 Cleo lamps, the intensity of the UV light coming from the solarium and reaching the skin decreases with distance as shown in Fig. 1. Here the intensity is measured using a Dr. Höhnlle UV-A/B meter.

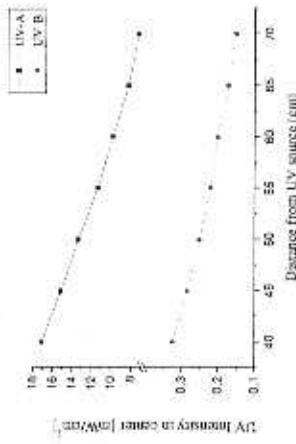


Fig. 1: Decrease of UV-A and UV-B intensity with distance from the UV source for a Philips HB8/2 solarium.

The amount of ethene that is emitted is found to be directly related to the intensity of the UV radiation. Fig. 2 shows the measured emission for a test person at 70 cm from the UV source (measured from the protection filter on the solarium). The maximum emission that is measured is quite low (about 0.5 ppb). Also, on the skin virtually no tanning is observed.

3.1.2. breath measurements

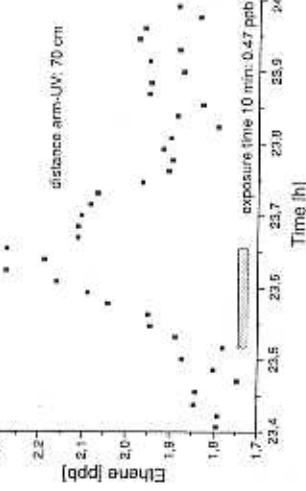


Fig. 2: Ethene emission due to UV exposure by Philips HB 8/12 solarium measured on 5 cm diameter area on skin on inside of an arm. Distance arm-UV source: 70 cm, total exposure time: 10 minutes, flow rate: 1 l/h.

Figure 3 shows a similar measurement taken from an arm of the same volunteer, but now at a shorter distance of 40 cm. Now the ethene emission is much higher, also the tanning effect on the skin is very clear.

Thus, it is seen that reducing the distance between the skin and the UV source from 70 cm to 40 cm, increases the UV-A and UV-B intensity by a factor of about 2.4. When skin is exposed to this increased intensity, the ethene peak emission at 10 minutes exposure increases by a factor 5.8, i.e. roughly by (intensity ratio)³ (compare Figs. 2 and 3).

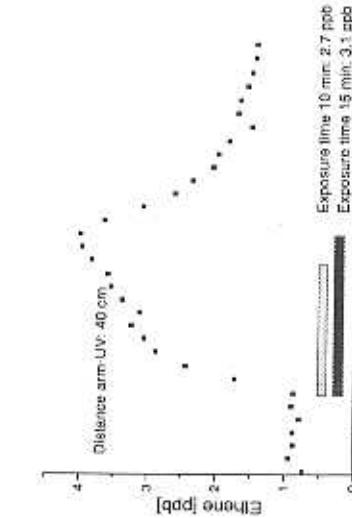


Fig. 3: Ethene emission due to UV exposure by Philips HB 8/12 solarium measured on 5 cm diameter area on skin on inside of an arm. Distance arm-UV source: 40 cm, total exposure time: 15 minutes, flow rate: 1 l/h.

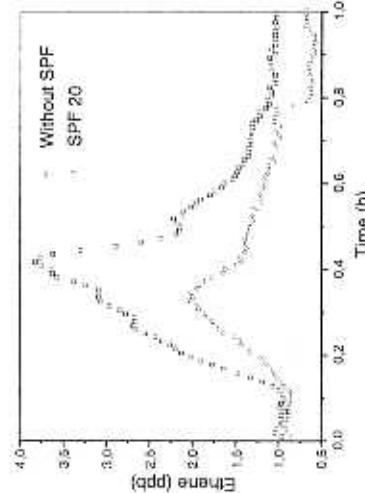


Fig. 4: Effect of UV radiation on human skin, monitored by ethene emission in exhaled air. The second graph shows the emission for the same person, now using a suntan cream with SPF 20. Exposure time: 15 minutes, flow rate: 3 l/h.

Due to the adaptation of the skin to UV radiation, a person can only be used for different full body exposure tests about once every five weeks (time for the adaptation to wear off). Although the full-body exposure that is needed to obtain a measurable signal in the breath

measurements therefore has a drawback, it also has several advantages. One of these is that it makes it possible to test the effects of UV sunfilters that are put on the body *in vivo*.

As most sun-creams contain fatty substances, measuring the protective effect from UV radiation using the skin cell is not trivial. This is due to the fact that the fatty substances in the cream may themselves produce ethene due to lipid peroxidation caused by UV irradiation. To reach the breath, the ethene produced by the cream first has to pass the skin barrier. Thus, most of the ethene that is present in exhaled air can be assumed to be produced in the skin, while the extra production by the cream will mostly be emitted directly. Therefore, using the breath test it is possible to test the protective effect of UV sunfilters. An example of this is shown in Fig. 4. Here an unprotected exposure is compared to an exposure while protected by a sunfilter with a sun protection factor (SPF) of 20. It is seen that the emission is decreased by as much as 75 %.

4. Discussion

Results obtained directly from the skin show that switching on the UV source results almost immediately in an increase in ethene emission, whereas switching it off results in a slightly slower decrease. Within 4 to 5 minutes from starting the exposure, a steady state situation is reached. When measuring the ethene content of exhaled breath, exposure effects of UV can be studied both with and without suntan cream. Without cream a more than ten-fold ethene increase (1.7 nmol/min after 15 min) during treatment is seen as compared to control emissions: 0.15 ± 0.05 nmol/min (average over 21 persons); suntan cream (sun protection factor 20) decreases the emission by 75%. When all UV radiation <400 nm is blocked (using lexane), no increase in ethene is found, proving that the measured effects are due to UV. In contrast to ethene signal directly from the exposed skin, the increase of ethene signal from breath after switching on the UV source is quite slow; also, the decrease appears to occur in two steps. In this case the ethene produced in the skin has to be transported through the body, reflecting the transport mechanism in the exhalation curve.

From these experiments it may be concluded that ethene is a good biomarker for lipid peroxidation and that the photoacoustic setup has the sensitivity required to perform on-line measurements to determine the effects of UV radiation on the skin.

5. Conclusions

Thus, photoacoustic trace gas detection allows the study of UV effects on human skin in several ways. It makes it possible to study fundamental aspects, like specific wavelength effects [4] by using different filter glasses, as well as the reaction of different types of skin on one person (face, arms, etc.). Also, the use of different sunprotection creams may be tested, *in vivo* and for different wavelength ranges.

In cooperation with medical specialists and industry many applications of this sensitive, non-invasive *in vivo* technique in studying UV effects on human skin are under investigation. These include clinical studies e.g. to test the effect of UV radiation on skin diseases like psoriasis, eczema and PLE (polymorphic light eruption). Measuring the ethene directly emitted by the skin allows the study of the reaction of skin of people with severe PLE, who cannot tolerate a total body exposure to UV. Furthermore, studies into the protective effect of certain diets on UV sensitivity of the skin will be undertaken.

6. References

- [1] B. Halliwell and J.M.C. Cutleridge (Eds.), 'Free radicals in Biology and Medicine', Clarendon Press, Oxford, (1985)
- [2] A. van Gossel and J. Decuyper, 'Breath alkanes as an index of lipid peroxidation', Eur. Respir. J., 2 (1989) 787-791
- [3] F.J.M. Harren and I. Reuss, 'Photoacoustic Spectroscopy', Encyclopedia of Applied Physics, (Ed.) G.L. Trigg (VCH, Weinheim, 1997), 413-435
- [4] F.R. de Grujil, 'Health effects from solar UV radiation', Radiation Protection Dosimetry, vol. 72(3-4), (1997), 177-196