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Original paper

Sunbeds' ultraviolet radiation measurements with different radiometers and criteria for compliance assessment set by the national competent authority in Greece

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ABSTRACT

In order to ground the credibility of the sunbeds' ultraviolet radiation compliance assessment with the 0.3 W/m^2 erythema effective irradiance limit, it is highly important to use reliable measuring equipment and to justify reasonably the measurement's result. Recently, the first surveillance action of the artificial tanning sector in Greece has been finalised. The action consisted of in situ erythema effective irradiance measurements from sunbeds at commercial premises offering artificial tanning services at various cities throughout Greece. Four different broadband erythemal weighted radiometers were used in order to compare them during in situ sunbeds' radiation measurements, at commercial premises, and to choose the most suitable one for compliance inspections. Furthermore a rationale has been introduced in order to compare the measurement's result with the limit, and decide about compliance or not, taking into account the measurement's expanded uncertainty. According to this approach, compliance, probable compliance or non-compliance is verified when the measurement's result taking into account the measurement's expanded uncertainty does not, probably or does exceed the 0.3 W/m^2 limit, respectively. Ultraviolet radiation exceeded the 0.3 W/m^2 erythema effective irradiance limit in 63.5% (33 out of 52) of the sunbeds and probably exceeded the limit in 11.5% (6 out of 52) of the sunbeds, according to the measurements performed with the radiometer which was chosen as the most suitable one and the proposed rationale for compliance justification.

1. Introduction

The European standard EN 60335-2-27:2013 applies in European Union (EU) and provides the limit values of the sunbeds' erythemal ultraviolet radiation (UVR) irradiance and the limit values of total erythemal dose [1]. Briefly, according to EN 60335-2-27:2013, the sunbeds' total UV (250–400 nm) erythema effective irradiance limit is 0.3 W/m^2 and the UVC (200–280 nm) irradiance limit is 0.003 W/m^2. Sunbeds should be characterized as UV type 1, 2, 3 or 4 device according to their erythema effective irradiance in the UVA (320–400 nm) and the UVBC (250–320 nm) spectrum [1]. Greece has adopted the above mentioned standard, through Hellenic Organization for Standardization (ELOT), as ELOT EN 60335-2-27:2013. EU encourages its member states to enforce safety requirements and regulations for the sunbeds and the provision of artificial tanning services.

Greek Atomic Energy Commission (EEAE) is the national competent regulatory authority for the control, regulation and supervision in the fields of nuclear energy, nuclear technology, radiological and nuclear safety, and radiation protection in Greece. In 2013, EEAE initiated a surveillance action of the artificial tanning sector in Greece. The action aimed to evaluate compliance of the sunbeds' radiation in Greece with the 0.3 W/m^2 limit set by ELOT EN 60335-2-27:2013, as it is the limit which almost all relevant national legislations and the EU recommendation (SCCP opinion 2006 [2]) have in common. It is worth mentioning that this was the first time that such action has ever been performed in the country. The results and conclusions of this action were utilized to form the national regulatory framework, in order to harmonize the artificial tanning sector in Greece with the ELOT EN 60335-2-27:2013 and the EU requirements, given that such legislation did not exist.

According to the literature, for sunbeds' erythema effective irradiance measurements, double monochromator spectroradiometers, single monochromator (diode or CCD array) spectroradiometers and broadband erythemal weighted radiometers have been used as measuring equipment [3,14]. The common

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practice among the competent authorities or the researchers has been to use either only a double [3,4] or single monochromator spectroradiometers [5–8]. Sometimes a broadband erythemal weighted radiometer was used for screening measurements and detailed measurements followed using a double or a single monochromator spectroradiometer [9–14].

Single and double monochromator spectroradiometers record a radiation source's emission spectrum, providing spectral information which is very helpful for understanding and characterizing the source's radiation [15–18]. Double monochromator spectroradiometers are considered the state of the art instruments for radiometric measurements. However they are very expensive, bulky and delicate instruments, spectral radiation recordings are time consuming and their operation and handling during in situ measurements is demanding [9,16,17]. Single monochromator spectroradiometers are easier to use than the double monochromator. However they suffer from high level of stray light which, without any corrections, could lead to severe measurement errors [16,19]. Also their potential to provide reproducible measurements is questionable [19]. Broadband radiometers measure integrated spectral radiation over a specific wavelength range. Special filters may be combined with the radiometer and in this case weighted radiation can be obtained directly [15,17]. Radiometers are handheld, easy to use and cost affordable instruments enabling effortless onsite measurements. Radiometers especially designed for UVR measurements from sunbeds are equipped with additional optical filters that approximate the CIE erythemal action spectrum. Thus the erythemal radiation is measured directly. Conventional radiometers for sunbeds' erythemal UVR measurements measure only total erythema effective irradiance over the UV spectrum, 250–400 nm. They cannot provide spectral information and for that reason they have only be used for screening sunbeds' UVR measurements during compliance inspections [5,6,9,10,13]. However, recently more sophisticated radiometers have been developed which are capable of performing simultaneously UVR measurements in the UV (250–400 nm), UVA (320–400 nm), UVBC (250–320 nm) or UVC (200–280 nm) range. Such radiometers might have the credentials to be used as measuring equipment during compliance inspections as they provide adequate information regarding radiation in the UV sub-ranges (UVA, UVBC, UVC) and are capable to assess compliance with all the limits set by the ELOT EN 60335-2-27:2013.

When a regulatory authority performs in situ sunbeds' UVR measurements for compliance assessment at commercial premises offering artificial tanning services certain points need to be taken into account. Firstly the inspections cannot be time-consuming in order not to obstruct the provision of services at the commercial premises unreasonably. Secondly, the measurements have to be solid as they are meant for compliance assessment. Double monochromator spectroradiometers are quite impractical for in situ measurements. Single monochromator spectroradiometers may be easier to use and measurements with them are faster compared to the double monochromator spectroradiometers but they are also not very practical for in situ measurements – too many pieces of equipment (diffuser or integration sphere, computer, spectroradiometer) and considerable amount of time to set the measuring apparatus are needed. Radiometers, however, enable quick erythema effective irradiance measurements, without exceedingly disturbing the premise's business routine.

Taking into consideration the abovementioned realistic and practical limitations, the decisive criteria which were set in order to choose the suitable measuring apparatus for the in situ sunbeds' UVR measurements during the first surveillance action of the artificial tanning sector in Greece were the functionality, practicality and convenience of the measuring equipment. In this direction, two identical single monochromator spectroradiometers and four different erythemal weighted broadband radiometers had been chosen as measuring equipment. The single monochromator spectroradiometers were equipped with a solarium mode stray light correction function which was accomplished by the software provided by the manufacturer together with the instrument. The correction that this software offered was realized by subtracting a constant value from the raw data but the performance of such a software based stray light correction is known as not to be so effective [18]. The repeatability and the measured erythema effective irradiance values of the two single monochromator spectroradiometers were questionable. Both of them consistently failed to provide reliable results – big differences (even higher than 50%) in the irradiance values were obtained when consecutive measurements were performed at the same measurement point inside the same sunbed. Also the measured erythema effective irradiance values were in some cases severely overestimated. For that reasons herein only the performance of the four different erythemal weighted radiometers, two "conventional" ones and two more "sophisticated", during in situ sunbeds' UVR measurements at solaria businesses in Greece is analysed and evaluated. The repeatability of each radiometer was much better than the single monochromator spectroradiometers (standard deviation was less than 0.005 W/m^2 and 0.0001 W/m^2 when measurements were performed with the "conventional" and the more "sophisticated" radiometers respectively). To the authors' knowledge, intercomparisons of radiometers, used in real practice for sunbeds' erythema effective irradiance measurements, have never been published. The present work contributes into covering that lack of information regarding practical sunbeds' erythema effective irradiance measurements with several types of radiometers.

Finally, it should be underlined that there is no explicit guideline regarding the robust assessment of excess of the 0.3 W/m^2 limit. Measurements are prone to uncertainties and this inherent characteristic affects the measured value. Therefore, when one has to compare a measurement's result with a limit value in order to decide about compliance, the measurement's uncertainty should not be overlooked. According to our knowledge, no methodology regarding the comparison of a measured sunbed's erythema effective irradiance value with the 0.3 W/m^2 limit, taking into consideration the measurement's uncertainty, has been defined. Herein a rationale is proposed, in order to rule when a measured erythema effective irradiance value exceeds, may exceed or does not exceed the 0.3 W/m^2 limit, taking into consideration the measurement's expanded uncertainty. An approach towards handling those cases when the measured values may or do exceed the limit, is also proposed.

To sum up, the aim of the present study was to choose the most suitable radiometer according to the intercomparison and to assess compliance with the 0.3 W/m^2 erythema effective irradiance limit according to the proposed criteria for compliance assessment taking into consideration the measurements expanded uncertainty.

2. Materials and methods

UVR measurements from vertical and horizontal sunbeds at artificial tanning premises all over Greece were performed from October 2013 to February 2015. Measurements consisted of erythema effective irradiance measurements at the UV (250–400 nm) spectral range. Erythema effective irradiance or irradiance measurements were also performed at the spectral ranges: UVA (320–400 nm), UVBC (250–320 nm) and UVC (200–280 nm) with the radiometers that were able to perform such measurements.