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Occupational Exposure to Solar Ultraviolet Radiation of Polish Outdoor Workers: Risk Estimation Method and Criterion

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This paper presents occupational skin exposure to solar ultraviolet radiation (UVR) of 122 Polish outdoor workers in spring and summer. In 65% of the cases, it was significant and exceeded 10 standard erythema doses (SED) during a work shift. The results provided grounds for (a) modifying hazard assessment based on the skin exposure factor proposed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and (b) developing a criterion of risk estimation. The modified method uses the UV index (UVI) instead of the geographical latitude and season factor. The skin exposure factor (W_{es}) of one is the criterion of risk estimation. Risk is low if the estimated value of W_{es} does not exceed one. If it does, suitable preventive measures are necessary and a corrected skin exposure factor (W_{es}^{*}) is calculated to minimize its value to at least one. Risk estimated with that method was high in 67% of the cases.

UVR hazard   solar UVR occupational exposure   risk assessment
risk estimation skin exposure factor

1. INTRODUCTION

Workers are exposed to ultraviolet radiation (UVR) both from the sun and from artificial sources. Exposure to UVR affects the skin and eyes. Adverse effects of that exposure can be acute and chronic. Acute effects occur within 24 h of excessive exposure to UVR and are generally short-term, as opposed to chronic effects, which are often gradual and long-term [1]. Photoconjunctivitis, photokeratitis, erythema and sunburn are acute effects. Long-term effects follow chronic or prolonged exposure. Solar keratoses, different kinds of skin cancer (including malignant melanoma), premature skin ageing (photoageing) and injuries to the eye like cortical cataract, carcinoma of cornea and pterygium are long-term effects. Therefore, the World Health Organization (WHO) considers the consequences of cumulative exposure to solar UVR a major problem. According to WHO, exposure to excessive solar UVR caused ~60 000 premature deaths around the world in 2000 [2]. The European Agency for Safety and Health at Work identified occupational exposure to UVR as a most important physical risk in the working environment and pointed to an increasing, even if not well documented, trend of exposure [3]. In 2006, Wolska, Flaspöler, Reinert, et al. found that ~14.5 million outdoor workers in 15 European Union states were exposed to solar UVR, i.e., ~7.4% of the total number of employed people at that time. However, these numbers reflected the scale of exposure only and could be underestimated [4].

Outdoor workers are exposed to solar UVR and so especially their skin is at an increased risk.

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Even though clothes should protect workers, the level of that protection is often insufficient.

Directive 2006/25/EC covers measures protecting workers from risks associated with artificial optical radiation only [5]. This means workers exposed to solar radiation still lack adequate protection against UVR. Since the health consequences of exposure to natural UVR can be serious, that risk should be considered during occupational risk assessment. Directive 89/391/EEC covers all hazardous factors related to occupational exposure irrespective of whether the source of hazard is artificial or natural [6]. So, its implementation requires considering workers exposed to both kinds of UVR. Occupational risk assessment of artificial optical radiation is based on criteria of hazard evaluation and exposure limit values in Directive 2006/25/EC. However, there are no criteria or exposure limit values for natural radiation. This paper presents both the results of measuring occupational skin exposure and related risk to solar UVR of Polish outdoor workers and a new criterion and modified method of estimating occupational risk related to solar UVR.

2. MATERIALS AND METHOD

2.1. UVR Exposure Measurements

Many studies on solar UVR exposure use personal dosimeters [7, 8, 9, 10, 11, 12, 13]. These are small broadband meters, which can be fixed to a worker's clothing or body. There are two kinds of dosimeters: active electronic and passive film ones (based on photo-induced changes in thermoplastic polysulphone); both are calibrated to measure erythemal effective radiant exposure. This study used an electronic dosimeter because it did not require additional calibration or measurement of time, it was reusable and had time-resolved storage of data [14]. Erythemal effective radiant exposure of natural UVR was measured with personal dosimeters X-2000-10 (Gigahertz-Optik, Germany) [8, 9]. The cosine-corrected detectors recorded erythemal irradiance with a time interval of 1 min. They were read off after the working day and erythemal radiant exposure was calculated with OS-X2000 software. The spectral responsivity of the dosimeters mimicked the erythemal effectiveness of the International Commission on Illumination (CIE) [15, 16]. Each dosimeter had a separate certificate of calibration from the manufacturer. Among the potential sources of UVR measurement errors of broadband radiometers, the most important are poor matching with the erythema spectrum and a mismatch between calibration source and source of the spectrum to be measured [17]. To minimize the measurement errors related to a mismatch between a CIE erythema action spectrum and the relative spectral responsivity of dosimeter, all dosimeters were additionally calibrated in laboratory conditions with the spectroradiometer system OL 750-C (Optronic Laboratories, USA) and a standard tungsten halogen lamp OL 200 IR (UVR: 250–400 nm). Erythemal effective radiant exposure ($H_{\text{ery-s}}$) was calculated from spectroradiometric measurements of spectral irradiance of a standard lamp with the CIE erythemal weighting function [15] and 5-min exposure. Erythemal effective radiant exposure ($H_{\text{ery-d}}$) during 5-min exposure to standard lamp radiation was measured for each dosimeter separately. Then, the calibration factors were calculated for each dosimeter:

$$C = \frac{H_{\text{ery-s}}}{H_{\text{ery-d}}}, \tag{1}$$

where $H_{\text{ery-s}}$ = erythemal effective radiant exposure measured with a spectroradiometer, $H_{\text{ery-d}}$ = erythemal effective radiant exposure measured with a dosimeter.

A spectral mismatch correction factor (F) minimized the error in measuring erythemal radiant exposure resulting from a spectral mismatch between irradiance distribution of a standard halogen lamp and solar radiation [18, 19]:

$$F = \frac{\int_\lambda S_{\text{sun}}(\lambda) S_{\text{ery}} d\lambda \cdot \int_\lambda S_{\text{std}}(\lambda) S_{\text{dos}} d\lambda}{\int_\lambda S_{\text{sun}}(\lambda) S_{\text{dos}} d\lambda \cdot \int_\lambda S_{\text{std}}(\lambda) S_{\text{ery}} d\lambda}, \tag{2}$$

where λ = wave length, $S_{\text{sun}}(\lambda)$ = spectral power distribution of solar radiation for terrestrial solar spectral irradiance (AM1.5 reference spectrum), $S_{\text{std}}(\lambda)$ = spectral power distribution of a standard lamp, $S_{\text{dos}}(\lambda)$ = relative spectral responsivity of a dosimeter, $S_{\text{ery}}(\lambda)$ = CIE erythemal reference action spectrum.

Erythemal radiant exposure measured with each dosimeter was multiplied by both *C* and *F*.

2.2. Field Measurements

Placing the dosimeters on the workers' shoulders was deliberate. This followed an analysis of exposure to sunlight measured on different parts of the body. The highest values were recorded for the shoulders [7, 12, 13, 20]. This location did not make work more difficult, which was an additional advantage.

The dosimeters were programmed to automatically start at the same time; they were placed on the workers' shoulders before the work shift. After the shift, the measurement stopped and the dosimeteres were collected. The workers were briefed about the objectives of the study. They were also asked to be careful with the dosimeters, especially in the vicinity of water and flames, and to prevent mechanical damage. The following data on environmental factors for each measurement day and place were collected: global solar UV index[1] (UVI), cloud cover, ground reflectance and shade. Also collected were personal factors: gender, age, job tenure, occupation, job during the shift, duration of exposure, description of clothes and the personal protective equipment worn that day.

Occupational exposure to natural UVR was measured in Poland in spring and summer over three years: 2008, 2009 and 2010.

2.3. Study Population

The 239 exposure measurements were done for 122 outdoor workers in 10 occupations: construction workers, road workers, security guards, gardeners, farmers, tracklayers, surveyors, fishermen, lifeguards and artists. Artists were selected as professionals who often work in the open air in summer (painting, weaving, etc.) and are, thus, exposed to natural UVR. Table 1 presents the population's characteristics.

3. RESULTS

3.1. Occupational Exposure to Natural UVR

Occupational exposure to natural UVR was evaluated with two parameters: erythemal radiant exposure (erythemal dose) during the work shift (in standard erythema doses[1], SED) and erythemal radiant exposure rate (erythemal dose rate) averaged over the duration of exposure (in standard erythema doses per hour). The erythemal dose represented the total erythemal dose during each worker's shift. As the duration and

TABLE 1. Workers' Characteristics

	Age (years)		Job Tenure (years)		Outdoor Work per Day (h)	
Occupation (*n*)	***M***	**Range**	***M***	**Range**	***M***	**Range**
Construction workers (18)	35.7	20–65	10.7	1–35	7.4	6.5–8
Surveyors (6)	36.4	21–55	10.6	1–33	7.7	3.5–11
Artists (10)	55.7	46–77	8.7	0.5–15	4.8	1–9
Security guards (4)	50.7	46–55	7.3	3–12	1.5	1–2.5
Gardeners (7)	30.2	23–39	1.6	2–5	7.2	4.3–8
Farmers (10)	43.3	24–57	19.5	6–38	8.7	8–9
Road workers (38)	39.9	23–57	14.3	1–40	5.4	3–6.5
Tracklayers (22)	43.5	32–60	14.9	0.08–40	8.2	7–10
Fishermen (3)	38.5	25–52	19.0	5–33	6.5	6.5
Lifeguards (5)	25.2	21–34	5.0	1–15	6.1	4–8.5
Artists (10)	55.7	46–77	8.7	0.5–15	4.8	1–9

[1] UVI is the measure of solar UV exposure rate, it uses the CIE erythema reference action spectrum. This is an international standard measurement of the strength of UVR from the sun in a particular place on a particular day.

time of work outdoors varied, the erythemal dose rate was also calculated and considered in the analysis of exposure to UVR.

Table 2 presents the erythemal doses for each occupation. In 65% of the cases, erythemal radiant exposure exceeded 1000 J/m^2 (10 SED), which corresponded to the minimal erythemal dose (MED) with adaptation[2] for skin phototypes III and IV [20, 21]. Table 3 presents the number of cases in individual occupations in which the erythemal dose of 10 SED was exceeded. Lifeguards (at the seaside), farmers, gardeners and tracklayers, who spent most time in open, unshaded areas, were most exposed to UVR. In lifeguards, the maximum dose (10 SED) was exceeded in all cases, because there was usually no shelter and sand reflected UVR. Fishermen were least exposed mostly because their working hours were between 1:00 and 7:00. Security guards, who worked outdoors mostly in the morning and no longer than 2.5 h a day, were not very exposed, either.

Table 4 lists the erythemal dose rates for each occupation. In 45% of the cases, they exceeded 1.25 SED/h (i.e., 10 SED/8 h = 1.25 SED/h). It should be noted that irrespective of the duration of exposure and the day of the measurement, the order of erythemal doses and erythemal dose rates was similar (Table 3).

3.2. Modified Method

According to the International Commission on Non-Ionizing Radiation Protection (ICNIRP), hazard posed by outdoor work can only be assessed semiquantitatively [20]. The method this paper proposes is based on ICNIRP's hazard assessment for skin exposure [20] and Standard No. EN 14255-3:2008 [14], both of which introduced the skin exposure factor, a product of multiplying the geographical latitude and season factor, cloud cover factor, duration of exposure factor, ground reflectance factor, clothing factor and shade factor. Then, the skin exposure factor is

TABLE 2. Erythemal Doses During a Work Shift by Occupation (SED)

Statistical Measure	Construction Workers	Surveyors	Artists	Security Guards	Gardeners	Farmers	Road Workers	Tracklayers	Fishermen	Lifeguards
Q1	12.75	4.01	2.91	3.71	14.56	15.67	6.13	10.67	0.15	22.98
Min	2.10	2.48	1.21	3.42	5.32	4.56	1.16	2.12	0.14	19.73
Mdn	20.26	6.29	4.09	4.33	16.87	22.76	10.73	17.84	0.15	26.73
Max	39.49	24.80	17.72	7.37	33.95	48.17	28.67	36.15	0.16	59.88
Q3	27.45	10.77	5.13	7.07	22.99	28.06	15.64	21.68	0.16	39.42
M	20.12	9.33	4.74	5.18	19.29	22.87	11.54	17.21	0.15	32.29
SD	9.75	7.65	3.24	1.89	8.00	10.69	7.06	8.53	0.02	14.68

Notes. SED = standard erythema dose, Q1 = lower quartile, Q3 = upper quartile.

TABLE 3. Excessive Exposure to Solar Ultraviolet Radiation by Occupation (%)

Exceeded Dose	Lifeguards	Farmers	Gardeners	Tracklayers	Construction Workers	Road workers	Surveyors	Artists	Security guards	Fishermen
10 SED/8 h	100	91	88	84	69	60	38	4	0	0
1.25 SED/1 h	100	91	94	84	88	84	31	19	0	0

Notes. SED = standard erythema dose.

[1] 1 SED = effective erythemal exposure of 100 J/m^2.
[2] Minimal erythemal dose (MED) with adaptation is the radiant exposure to UV that produces a just noticeable erythema on a previously three weeks exposed skin without erythema [21].

TABLE 4. Erythemal Dose Rates During a Work Shift by Occupation (SED/h)

Statistical Measure	Construction Workers	Surveyors	Artists	Security Guards	Gardeners	Farmers	Road Workers	Tracklayers	Fishermen	Lifeguards
Q1	1.66	0.77	0.68	0.67	1.72	2.36	1.21	1.46	0.02	3.14
Min	0.30	0.45	0.40	0.54	0.57	0.80	0.23	0.27	0.02	2.32
Mdn	2.66	0.97	0.79	0.79	2.09	2.80	1.93	2.05	0.02	3.76
Max	5.64	3.15	5.91	3.42	4.42	5.66	6.35	4.59	0.03	7.48
Q3	3.54	1.48	1.32	1.09	3.26	3.46	3.00	2.75	0.02	6.43
M	2.68	1.27	1.20	1.30	2.41	2.98	2.16	2.16	0.02	3.10
SD	1.28	0.78	1.17	1.20	1.21	1.17	1.27	1.09	0.00	3.82

Notes. SED = standard erythema dose, Q1 = lower quartile, Q3 = upper quartile.

compared with recommended skin protection [14, 20] to choose suitable protective measures. Following the measurements of UVR exposure in Poland, some changes were introduced in the method, but the idea of semiquantitative assessment remain the same. This means that no specific measurements in the working place are necessary and risk is estimated on the basis of environmental and work-specific factors only. The proposed method substitutes the geographical latitude and season factor with the UVI for a particular geographical place and day (maximum UVI for a clear sky). Thus, the risk of a potential underestimation of hazard on days with a high UVI (over 6) is avoided, especially for areas north of lat 50°N latitude (i.e., most of Poland). This change was possible because the Institute of Meteorology and Water Management – National Research Institute (IMGW) posts maps of predicted maximum UVI for Poland for the next day on its website.

In addition to values proposed by ICNIRP and Standard No. EN 14255-3:2008, some additional ones were introduced. A value of 0.50 was introduced for the cloud cover factor for medium cloudiness (i.e., clouds often but not completely covering the sun). This value was estimated on the basis of erythemal irradiance measurements for different cloud cover. Considering the most common clothing of outdoor workers in Poland, it was necessary to introduce additional values of the clothing factor. Epidemiologic evidence shows that UV-related skin tumours are often found on the neck and head, and on the torso and arms. Considering the percentage of individual body skin surface areas, three values for the clothing factor were introduced:

- 0.40 for the condition of the torso and legs protected; arms, head and neck exposed (short sleeves, long trousers, no headgear);
- 0.35 for the condition of the torso, legs and head protected; arms and neck exposed (short sleeves, long trousers, a peaked cap);
- 0.07 for the condition of the torso, legs and arms protected; head and neck exposed (long sleeves, long trousers, no headgear).

The values of the cloud cover, ground reflectance, clothing, shade and duration of exposure factors were the same as in Standard No. EN 14255-3:2008 [14], ICNIRP [20] and Wolska and Latała [22].

In the proposed method, two skin exposure factors are calculated: (a) the skin exposure factor (W_{es}) to assess risk when there are no protective measures; it reflects the severity of skin exposure to solar UVR accounting for environmental factors (i.e., UVI, clouds and ground reflectance); (b) the corrected skin exposure factor (W^*_{es}) to assess risk when protective measures (e.g., clothing, duration of exposure, shade) are in place. In this way, environmental factors (which are independent of workers and employers) are distinguished from dependent factors (which employers can change to minimize workers' exposure). The two factors are calculated with Equations 3 and 4, respectively [22]:

$$W_{es} = UVI \cdot W_1 \cdot W_2, \quad (3)$$

where W_{es} = skin exposure factor, *UVI* = maximum UVR index (predicted for a clear sky in a particular geographical place and day), W_1 = cloud cover factor, W_2 = ground reflectance factor;

$$W^*_{es} = W_{es} \cdot W_3 \cdot W_4 \cdot W_5, \tag{4}$$

where W^*_{es} = corrected skin exposure factor, W_{es} = skin exposure factor, W_3 = clothing factor, W_4 = shade factor, W_5 = duration of exposure factor.

3.3. New Criterion for Risk Estimation

The following assumptions were made to define the criterion for estimating risk caused by solar UVR:

- maximum erythemal dose during a work shift is 1000 J/m^2 (10 SED), which corresponds to MED with adaptation for skin phototypes III and IV [20, 21];
- maximum duration of a work shift is 8 h;
- there is a mathematical relation between erythemal dose rates (H_r) and skin exposure factors (W_{es}).

MED with adaptation was developed separately for skin phototypes I and II (600 J/m^2) and III and IV (1000 J/m^2) [20, 21]. An epidemiological study on adverse health effects resulting from exposure to natural UVR showed that over 62% of Polish outdoor workers had skin phototypes III and IV (no one had skin phototype I) [23]. Thus, MED with adaptation for phototypes III and IV was chosen for the development of the criterion.

Data on environmental factors (maximum UVI, cloud cover, ground reflectance) were used to calculate the skin exposure factors (W_{es}) for each measurement day and place. Erythemal exposure rates were collected for each of the 11 selected values of W_{es}, and the following values of descriptive statistics were calculated: minimum, lower quartile (Q1), median, upper quartile (Q3) and maximum. To protect the workers' health, it was additionally assumed that the maximum values of erythemal dose rates for particular W_{es} should be considered. The analysis of regression using different functions was carried out. A higher value of the coefficient of determination (R^2) was calculated for linear regression between erythemal dose rates (H_r) and skin exposure factors (W_{es}):

$$H_r = 1.1758 \cdot W_{es} + 0.0037, \tag{5}$$

The calculated coefficient of determination R^2 = .558 means that ~56% of variation in ery-

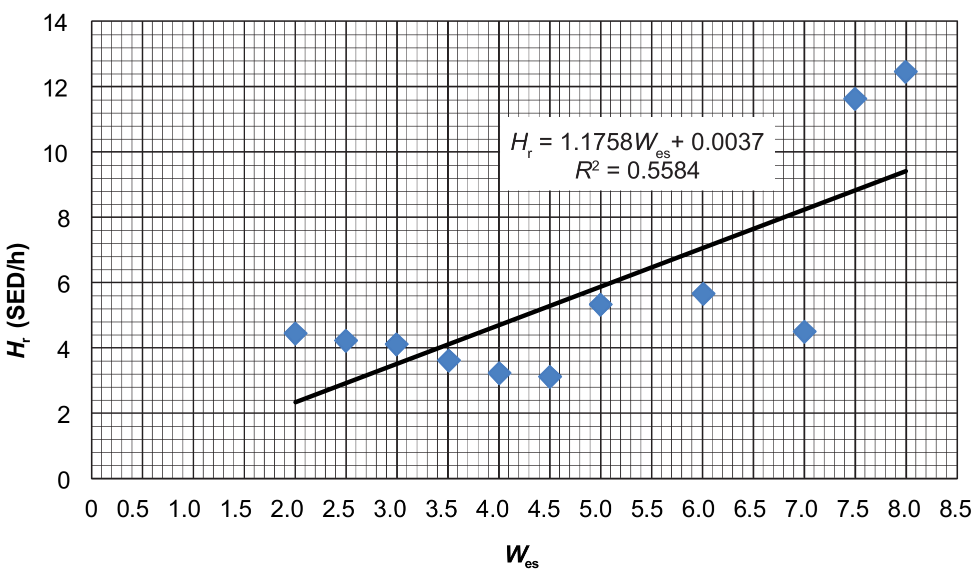

Figure 1. The relation between erythemal dose rates (H_r) and skin exposure factors (W_{es}).

themal dose rates is described by the variation in skin exposure factors using this linear function (see Figure 1). It must be stated that H_r was measured at work, with workers performing normal activities, so shadows cast by other workers, equipment and the environment strongly influenced the results. That was the main reason of a big differentiation of H_r for the same value of W_{es}.

Taking into account the assumed maximum erythemal dose during a work shift of 10 SED and maximum duration of exposure of 8 h, the maximum erythemal dose rate is 1.25 SED/h. This means that during an 8-h day shift, the erythemal dose rate should not exceed 1.25 SED/h. For an erythemal dose rate of 1.25 SED/h, the calculated value of the skin exposure factor W_{es} is 1.06. Thus, the following criterion of risk estimation was assumed: if estimated $W_{es} \leq 1$, occupational risk is low and no additional preventive measures are necessary. If estimated $W_{es} > 1$, suitable preventive measures are necessary and corrected skin exposure factor W^*_{es} should be calculated to minimize its value to at least one. This means that if all preventive measures (suitable clothes, duration of exposure, shade) are used, the risk is reduced to low and is acceptable.

3.4. Examples of Risk Estimation

Table 5 presents results of sample risk estimation carried out with the new method and criterion. In most cases, the values of W_{es} indicated the need to use protective measures and to calculate W^*_{es}. Only during the days of low UVI and an overcast sky (W_1 = 0.2 [14, 20]), was the value of W_{es} under one, i.e., no additional protective measures were necessary and it was not necessary to calculate W^*_{es} (see the road worker in Table 3).

It is clear that in most cases (67%), risk was high, which means the preventive measures were not suitable. This risk could always be reduced with additional preventive measures, especially suitable clothes that covered exposed parts of the body.

4. DISCUSSION AND CONCLUSIONS

The population of Polish outdoor workers is moderately insensitive to sunlight (skin phototype III); usually their skin is adapted to sunlight because of frequent exposure. Thus, it was assumed that daily exposure of 10 SED, which is MED with adaptation for skin phototype III, would be the exposure limit for outdoor workers.

TABLE 5. Examples of Occupational Risk Estimation

Occupation (Job)	*UVI*	W_1	W_2	W_{es}	W_3	W_4	W_5	W^*_{es}	Risk
Construction worker (timbering)	7.3	1.00	1.00	7.30	0.50	1.00	1.00	3.65	high
Crane operator (carrying a load)	7.3	1.00	1.00	7.30	0.35	0.02	1.00	0.05	low
Road worker (asphalting)	3.1	0.20	1.00	0.62	0.35	1.00	1.00	0.22	low
Lifeguard (watching people bathe)	6.5	1.00	1.20	7.80	1.00	0.30	1.00	2.34	high
Lifeguard (watching people bathe)	6.5	0.70	1.20	5.46	0.50	1.00	1.00	1.36	high
Tracklayers (installing a tram line)	7.0	0.50	1.00	3.50	0.02	1.00	1.00	0.07	low
Tracklayers (installing a tram line)	7.0	0.50	1.00	3.50	0.35	1.00	1.00	1.23	high
Surveyor (measuring land)	7.0	0.70	1.00	4.90	0.40	1.00	1.00	1.96	high
Surveyor's assistant (measuring land)	7.0	1.00	1.00	7.00	0.35	1.00	0.50	1.22	high
Farmer (working in the field)	6.0	1.00	1.00	6.00	0.40	1.00	0.50	1.20	high
Farmer (hay-making)	6.0	0.70	1.00	4.20	0.10	1.00	1.00	0.42	low
Gardener (weeding)	8.0	1.00	1.00	8.00	0.45	1.00	0.50	1.80	high
Gardener (planting)	8.0	0.70	1.00	5.60	0.50	0.3	1.00	0.84	low

Notes. UVI = ultraviolet radiation index; W_1 = cloud cover factor, W_2 = ground reflectance factor, W_{es} = skin exposure factor, W_3 = clothing factor, W_4 = shade factor, W_5 = duration of exposure factor, W^*_{es} = corrected skin exposure factor.

It was used as an assumption in the developed criterion of risk estimation. Measurement results of erythemal radiant exposure showed that occupational exposure to natural UVR in spring and summer in Poland was significant and exceeded 10 SED per work shift in 65% of the cases. In lifeguards, the maximum dose (10 SED) was exceeded in all cases, because they usually worked without any shelter, sand reflected UVR and they always worked at least 2 h around midday. In two groups, fishermen and security guards, all-day doses were under 10 SED. This could be explained by the specific duration of exposure of those two groups: fishermen usually finished work early in the morning, and security guards worked outside at most 2.5 h a day and usually most of that time is in the morning. Regardless of the duration of exposure, geographical location (lat 30°–50°N or north of lat 50°N) and cloud cover, erythemal radiant exposure rates exceeded 1.25 SED/h in 45% of the cases. Geographically, most of Poland is north of lat 50°N and UVI maps clearly show that in that area the values of UVI vary. In the rest of Poland, i.e., south of lat 50°N, the values of UVI are generally higher, but in the border zone around lat 50°N, UVI is often the same. In the method of hazard assessment proposed by ICNIRP [20] and Standard No. EN 12455-3:2008 [14], the geographical latitude and season factor for both considered areas in spring and summer differs significantly, with the values of 4 or 7, respectively. This means that if in the locality *X* south of lat 50°N and in the locality *Y* north of lat 50°N, the value of UVI is the same, hazard assessment according to the ICNIRP [20] and Standard No. EN 12455-3:2008 method will give different results for the two places. Besides, for all spring and summer, regardless of changes in UVI, the assessment uses the same value of the factor. These results provided ground for implementing changes in the method of hazard assessment based on the skin exposure factor [14, 20], especially to substitute the geographical latitude and season factor with the maximum predicted UVI for a clear sky and for the particular geographical place and day. Using UVI, which is proportional to the erythemal dose, makes estimating risk more accurate and restrictive. This method can be used all over the world regardless of geographical latitude because UVI is monitored everywhere and access to information on it is free. However, the criterion was developed for workers with skin phototypes III and IV (i.e., melano-competent), which restricts the use of that method to outdoor workers with these skin phototypes, whether in Europe or elsewhere. For workers with skin phototypes V and VI (i.e., melano-protected), the criterion for risk estimation will be much higher because the values of MED with preadaptation to UVR are much higher: 60 and 80 SED for skin phototypes V and VI, respectively [20, 21].

The results of risk estimation conducted with the new method and criterion showed that the clothes Polish outdoor workers wear often do not protect against UVR. For example, workers do not wear brimmed hats. Peaked caps and helmets (among construction workers), which do not protect the neck, are the most popular headgear. The practice of workers wearing any work clothes they choose should change, too. Another important observation is that employers do not use organizational measures to limit exposure to solar UVR. They do not, e.g., limit the duration of exposure at midday; rotate workers, especially those highly exposed to UVR; assign work in shaded places or provide personal protective equipment against UVR for the head, neck and eyes.

The two skin exposure factors, without (W_{es}) and with protective measures (W_{es}^{*}), help the employer to assess the need for and effectiveness of protective measures. In most cases, W_{es} indicates the need to use protective measures, which is also important from the educational point of view, because the employer and the workers become more aware of the hazard related to natural UVR and of the need and significance of protective measures.

The developed method was presented at seminars for workers responsible for occupational safety and health, who considered it simple and useful. Thus, implementing the method should help to increase workers' awareness of hazards related to exposure to UVR and of the need to comply with the principles of protection. In future, this should result in a decrease in adverse health effects. Moreover, outdoor workers with melano-competent skin phototypes all over the world can benefit from the developed method and criterion.

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