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UV solar exposure of outdoor workers in Mediterranean area

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***Abstract*—The exposure to UV solar radiation can have several adverse health effects. During summer in Mediterranean area high UV irradiation levels occur and outdoor workers may incur in overexposure risk. This paper reviews the measurement campaigns of UV solar exposure carried out in Mediterranean area.**

Keywords—solar radiation, occupational, erythemal, measurement.

I. Introduction

The Mediterranean area is extended between the latitude 30° and 47° N and for this it has a temperate clime; nevertheless, in Summer season high UV irradiation levels are recoded. Figure 1 shows the daily erythemal UV Index (UVI) [1] in Europe in a Summer day (21st July) provided from the TEMIS service [2]: in the Mediterranean area UVI values between 9 and 11 have been recorded.

Outdoor workers in Mediterranean area have high risk to incur in adverse health effects consequent to UV solar radiation overexposure. Health diseases related to excessive exposure to UV radiation involve skin and eyes and may be acute or long-term effects of exposure: they include erythema, non-melanoma and melanoma skin cancer, photokeratitis, photoconjunctivitis and cataract.

The assessment of worker's exposure to UV radiation is important under the aspects of prevention, protection and diagnosis. This paper presents a review of the scientific measurement campaigns carried out in Mediterranean area in the recent years with the aim of comparing the experiences.

The European Directive 2006/25/CE established a threshold limit of exposure to the artificial optical radiation of H_{eff} = 30 J/m^2 over an interval of 8 hours: it corresponds to a SED of about 100 J/m^2.

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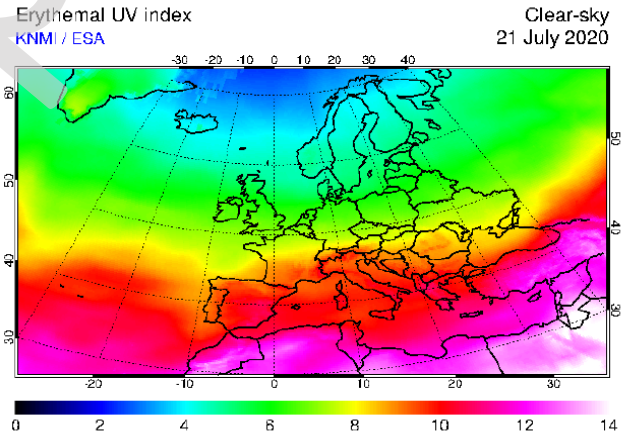


Figure 1. UVI in Europe in a summer day (TEMIS)

II. Method

A. Articles selection

The articles search database "Scopus" has been queried with the following keywords: solar radiation + outdoor workers; solar exposure + occupational; measure erythemal exposure.

Results were firstly filtered basing on title and abstract: 31 articles were extracted and analyzed. They treated measurement campaigns of UV solar exposure all over the World: among these, 10 articles regarded the measure of workers' exposure in Mediterranean area and were considered for the analysis. Another article, published in a national Journal of the sector was added, for a total of 11 papers.

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The articles, ordered for publication data are: Milon et al. (2007) [3], Serrano et al. (2009) [4], Sisto et al. (2009) [5], Serrano et al. (2013) [6], Miligi et al. (2013) [7], Nardini et al. (2014) [8], Modenese et al. (2019) [9], Wittlich et al. (2020) [10], Kovačić et al. (2020) [11] Modenese et al. (2020c) [12], and Modenese et al. (2020d) [13].

B. *Analysis*

The 11 selected articles were read and analyzed in the following aspects:

- Work typology;
- Number of participants;
- Period of measurement campaign: season/month, number of days, hours;
- Environmental conditions: whether conditions, setting typology;
- Instruments typology (dosimeters, radiometers) and their position;
- Measured dimensions: UV irradiance, effective radiant exposure H_{eff}, SED, UVI;
- Body districts considered.

For the paper Wittlich et al. [10] only the data referred to the 2 measurement campaigns carried out in the Mediterranean area were considered.

III. Results

The 11 selected articles were published from 2007 to 2020: the temporal distribution is showed in the graph of figure 2.

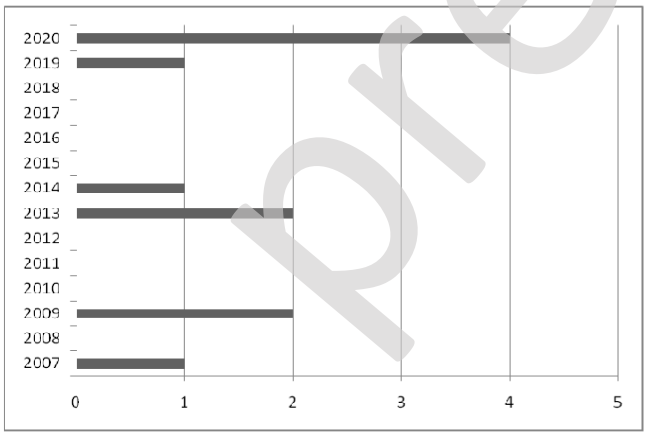


Figure 2. Year of publication of the papers

The papers can be grouped in three periods with intervals of some years between one and the other: the number of papers published in the 2019-2020 indicates a renewed interest for the problem in the last years.

The measurement campaigns regarded a wide typology of works and some papers investigated more than one work [4][7][13]; the number of workers that participated to the measurement campaign was generally less then 10 people (see Table 1); gender and age of participants were generally not specified.

TABLE I. Work and workers information

Paper	*Work typology*	*Number of workers*
Kovacic et al. (2020)	construction	4
Miligi et al. (2013)	agricolture	From 13 to 22
	fishing	
Milon et al. (2007)	construction	20
Modenese et al. (2020a)	construction	3
Modenese et al. (2020b)	longshore	10
	traffic coordination	4
Modenese et al. (2019)	fishing	7
Nardini et al. (2014)	agricolture	6
Serrano et al. (2009)	gardeners	4
	lifeguards	5
Serrano et al. (2013)	costruction	8
Sisto et al. (2009)	-	From 13 to 22
Wittlich et al. (2020)	construction	4+4

The environmental conditions indicated a small geographic distribution: the campaigns were located in three countries (most of them were carried out in Italy) and often in recurring places of measurements; table 2 indicates also that different environments were investigated.

TABLE II. Environment information

Paper	*country*	*location*	*setting*	*altitude (m)*
Kovacic et al. (2020)	Croatia	Zagreb	-	128
Miligi et al. (2013)	Italy	Siena	rural	300
		41°-43° N	sea	0
Milon et al. (2007)	Switzerland	Valais	mountain	500-600 1400-1500 2000-2500
Modenese et al. (2020a)	Italy	Siena	-	-
Modenese et al. (2020b)	Italy	Trieste	port	0
Modenese et al. (2019)	Italy	North-West Adriatic Sea	sea	0
Nardini et al. (2014)	Italy	Marche	farm	195
Serrano et al. (2009)	Spain	Valencia	university campus	0
		Malvarrosa	beach	0
Serrano et al. (2013)	Spain	Valencia	university campus	0
Sisto et al. (2009)	Italy	Siena	rural	300
Wittlich et al. (2020)	Italy	Siena	-	-
	Croatia	Zagreb	-	-

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Table 3 shows that the campaigns of measure were carried out principally in Summer and some of them in Spring, when the risk of exposure is higher; nevertheless, in many cases only few days were recorded and only few studies investigated a long period. Many measurements were performed in cloudless sky conditions, while the information is not available when the campaign lasts many days: probably, in these cases, many sky conditions occurred.

TABLE III. TIMING AND WEATHER INFORMATION

Paper	*months*	*duration*	*hours*	*sky*
Kovacic et al. (2020)	Jun-Oct	-	07:00-18:00	-
Miligi et al. (2013)	Apr, Jul, Oct	3 d	-	variable
	Jul	-	-	clear
Milon et al. (2007)	Jul-Sep	2-4 h	10:00-16:00	cloudless
Modenese et al. (2020a)	May-Jun	23 d	09:00-17:00	-
Modenese et al. (2020b)	Jul	1 d	Full working day	-
Modenese et al. (2019)	May	2 d	07:00-14:00	cloudless
Nardini et al. (2014)	Apr, May	19 d	10:00-12:00 14:00-16:00	-
	Jun	8 d		
	Jul	8 d		
	Ago	5 d		
	Sep	16 d		
Serrano et al. (2009)	Jun	4 d	06:00-13:00	cloudless
	Jul	4 d	10:00-19:00	cloudless
Serrano et al. (2013)	Jul	5 d	08:00-14:00 15:00-19:00	-
Sisto et al. (2009)	Apr, Jul, Oct	-	-	variable
Wittlich et al. (2020)	May-Sep	5 days per week	07:00-17:00	-
	Jun-Oct			

In many articles the effective radiant exposure or dose not was the only dimension measured, but often the UV irradiance on the horizontal plan was recorded and sometime the UVI or the SED was calculated. Moreover, many studies measured the exposure of several body districts. The following table 4 shows the information regarding the measurement conditions.

TABLE IV. MESUREMENT INFORMATION

Paper	*Instrument*	*weighting*	*Dimensions*	*position*
Kovacic et al. (2020)	dosimeters	erythemal	UV-A and UVB/C irradiances, SED	Left upper arm
	Meteorological station	-	UV daily dose	-
	TEMIS	Erythemal, vitamin D, DNA-damage	daily dose	
Miligi et al. (2013)	Polysulphone dosimeters	-	-	Arm, back
	Film dosimeters	-	-	Back, heat, arms
Milon et al. (2007)	Film dosimeters	CIE	Effective daily exposure, SED, percent of ambient exposure	Neck, shoulder, low back, forehead
	dosimeter	-	Static UV irradiance	horizontal
	Baseline Surface Radiation Network	-	Daily irradiation cycles	-
Modenese et al. (2020a)	Elctronic dosimeters	erythemal	UV-A and UVB/C irradiances	Left upper arm
	ESA database	erythemal	Total environmental UV dose	-
Modenese et al. (2020b)	Electronic dosimeters	-	Personal UVR exposure, ocular UVA dose	Chest, back, sunglass
	Spectro-radiometer	-	Environment UV radiant exposure	-
	ESA	erythemal	Effective radiant exposure	Horizontal plan
Modenese et al. (2019)	Electronic dosimeters	Unweighted, CIE erythemal, ICNIRP erythemal actinic	Solar UV exposure	Back, chest, nape, sunglass
	Spectro-radiometer	-	Environment UV exposure	Horizontal plan
Nardini et al. (2014)	Spectro-radiometer	-	irradiance	Horizontal plan
	Personal dosimeters	CIE erythemal	UVR exposure	Cheek, nape, forehead, forearm
Serrano et al. (2009)	Spore-film dosimeters	CIE erythemal	Solar erythemal exposure, MED (type II), SED	Shoulder, wrist
	PMA detector		Ambient UVR	roof
Serrano et al. (2013)	Spore-film dosimeters	CIE erythemal	SED	Shoulder, chest
	UVB radiometer	erythemal	Ambient UVR	roof
Sisto et al. (2009)	Polysulphone film dosimeters	CIE erythemal	UVA and UVB solar irradiance, effective dose	Arm, back
	-	-	Skin reflectivity, external cutaneous temperature	Cheek, inner arm

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Paper	*Instrument*	*weighting*	*Dimensions*	*position*
Wittlich et al. (2020)	Electronic dosimeters	-	UVR exposure	Left upper arm

IV. Discussion

Results of articles selection evidenced that only 11 papers regarding measurement campaigns of the UV solar radiation exposure of outdoor workers in Mediterranean area have been published in 14 years (less than 1 per year); moreover, the measurement campaigns were carried out in only four European countries (Italy, Spain, Croatia and Switzerland), while no articles regard the Asiatic and North African countries. This could be due to the use of a single search database, but it indicates that the problem of workers' overexposure to UV solar radiation and the related health risks are poorly or not considered in many Mediterranean countries, particularly in the South regions where the health risks are greater due to the higher UV irradiation levels.

On the contrary, where the problem of outdoor workers' protection against UV solar radiation has considered, significant the measurement campaigns have been carried out. Results of analysis indicated that the UV solar exposure of a large variety of outdoor woks has been measured in several environmental conditions: this demonstrate that this theme has a large extension and involves a big number of workers. At the same time, the collection of many data consents to compare the different exposures and it is a first step through the systematization.

Summer and Spring were the periods mostly investigated: even in these two seasons exposure risks are grater, in the Mediterranean area the erythemal exposure should be monitored in all seasons, since high irradiance levels can be recorded also in Winter [14].

Regarding the method of measure, the articles analysis demonstrated a substantial uniformity: about all studies used personal dosimeters erythemally weighted (generally with the CIE curve) and the measure of effective radiant exposure was often combined with the environmental UV radiant exposure measured on the horizontal plan with spectroradiometers or derived from satellite data. The dosimeters were worn in different positions, and this allows to obtain exposure information on many body districts.

V. Conclusion

The analysis performed on the selected article indicated that in many regions of the Mediterranean area the health risks connected to overexposure to UV solar radiation of outdoor workers seems underestimated for the absence of publications regarding measurement campaign on this theme.

Instead, the article selected contains significant measured data, of several work typologies, environmental settings and body districts. Results of these measurement campaigns could compose the first step of a database collecting and systematizing the erythemal exposure of outdoor workers.

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