Journal Homepage: - www.journalijar.com
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)
Article DOI:10.21474/IJAR01/2789
DOI URL: http://dx.doi.org/10.21474/IJAR01/2789

RESEARCH ARTICLE

HEALTH EFFECTS OF LOW LEVEL IONIZING RADIATION COMPARED TO ESTIMATED UV INDEX IN SHARM EL-SHEIKH, EGYPT.

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Manuscript Info

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Manuscript History

Received: 15 November 2016
Final Accepted: 17 December 2016
Published: January 2017

Key words:-
Ultraviolet index, clear sky global solar radiation, temperature, erythema, somatic, genetic, teratogenic and transgenerational.

Abstract

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Background: The interest in solar ultraviolet (UV) radiation from the scientific community and the general population has risen significantly in recent years because of the link between increased UV levels at the Earth's surface and depletion of ozone in the stratosphere. However, Ultraviolet (UV) radiation is a well-known physical hazard responsible for photoaging, photoallergic, and phototoxic reactions as well as carcinogenesis. On the other side, ionizing radiation is known as one of the detrimental factors in the work environment that can cause serious, irreversible and irreparable damages in professional radiation workers, but the effects of low doses on human health has not been completely known.

The Aim: The study clarifies the late and low level effects of ionizing radiation on health and recognizes the adverse effects of excessive solar radiation on skin, eyes and the immune system. It also outlines new approaches on how to improve the effectiveness of the UVI as a public awareness tool toward encouraging sun protection behavior aiming to reach a simplified estimation method and accurate predictive results for daily clear sky global solar radiation (H) and daily maximum ultraviolet index (UVI_{max}).

Methods: A simplified estimated model and accurate prediction results of UVI_{max} are reached in this work. The linear multiple-regression model is used to forecast the UVI_{max} for state of Sharm El-Sheikh. The precision of the developed forecasting model of daily UVI_{max} is based on maximum temperature and accurate prediction results of daily H. The linear multiple- regression empirical model for estimating daily global solar radiation is based on three -predictor variables and one response variable.

Results: The predictor variables of the daily global radiation (H) developed model are different from predictors of other existing models. The developed model is considered as a simplified statistical approach because it depends on two constant predictors and one changeable predictor. It shows that the predicted global solar radiation

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overlaps the measured global solar radiation in all months of the year. The UVI refers to the daily maximum effective irradiance and serves as an indicator of the impact of UV-radiation on erythema (sunburn). It was developed as a tool to conceptualize the amount of harmful radiation and to encourage the general public to use sun protection, and it is recommended to be integrated with broader public health approaches. By comparing to late and low level effects of ionizing radiation, there are four types of delayed radiation effects: somatic, genetic, teratogenic, and transgenerational. The current radioprotection guidelines state that all exposures to radiation should be avoided if possible and that exposure should be kept as low as is reasonably achievable.

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Introduction:-

Ultraviolet (UV) radiation is a well-known physical hazard responsible for photoaging, photoallergic, and phototoxic reactions as well as carcinogenesis, including life-threatening melanomas **(Zuba et al., 2016)**. Solar radiation is an important natural factor because it forms the Earth's climate and has a significant influence on the environment. The ultraviolet part of the solar spectrum (UV) plays an important role in many processes in the biosphere. It has several beneficial effects but it may also be very harmful if UV exceeds"safe" limits. If the amount of UV radiation is sufficiently high the self-protection ability of some biological species is exhausted and the subject may be severely damaged. This also concerns the human organism, in particular the skin and the eyes (**Allinson et al., 2012)**. Overexposure to both natural and artificial UV radiation is a public health concern. 30% of cancers diagnosed worldwide are skin cancers. Approximately three million non-melanoma skin cancers and 132 000 new cases of melanomas are diagnosed globally each year. Sunburns, especially in childhood, are a very important risk factor for melanomas. Several studies demonstrated a positive association between sunbed use and an increased incidence of malignant melanoma **(Zuba et al., 2016)**.The International Agency for Research on Cancer has noted that there is sufficient evidence from studies in animals and in man to establish ultraviolet radiation as a human carcinogen. Skin cancer has been the most commonly studied cancer site with respect to UV radiation. The nature and timing of sun exposure appear to be important determinants of both the degree of risk and the type of skin cancer. Cutaneous malignant melanoma and basal cell cancer are much more strongly related to measures of intermittent ultraviolet exposure (particularly those of childhood or adolescence) than to measures of cumulative exposure. In contrast, squamous cell cancer is more strongly related to constant or cumulative sun exposure. Lip cancer is causally related to lifetime sun exposure. It has been estimated that solar ultraviolet radiation accounts for approximately 93 percent of skin cancers and about half of lip cancers**(Gallagher et al., 2010)**.

The diurnal and annual variability of solar UV radiation reaching the ground is governed by astronomical and geographical parameters as well as by the atmospheric conditions. As a consequence, solar UV radiation is a highly variable environmental parameter that differs widely in time and space. The need to reach the public with simple-to-understand information about UV and its possible detrimental effects led scientists to define a parameter that can be used as an indicator of the UV exposures. This parameter is called the UV Index (UVI) **(Allinson et al., 2012)**. It was introduced in 1995 by the World Health Organization (WHO), the United Nations Environment Programme (UNEP), the World Meteorological Organization (WMO), and the International Commission for Non-Ionizing Radiation Protection **(ICNIRP, 1995)**. UVI is a unit of measure of UV levels relevant to the effects on human skin. The UVI is now widely used in many operational weather reports and forecasts. In Europe, for example, there are more than a dozen forecasting centers that release estimated UVI values for countries or regional areas. Different methods are used to predict the UVI and all kinds of information systems and presentations are seen. Operational UVI forecasting has already been implemented in many countries. The forecast methods vary from simple statistical methods used for local areas to more complicated methods with global coverage and with forecast times from a few hours to several days, either for clear sky or all sky conditions **(Allinson et al., 2012)**. Many researchers have a try to achieve to the best empirical models for estimating the daily global solar radiation by using different equations based on one independent variable such as: mean relative sunshine duration (S/S_0). These equations represented in linear, exponential, power, logarithmic, quadratic, cubic, linear exponential and linear logarithmic **(Marwal et al., 2012; Medugu and Yakubu, 2011; Muzathik et al., 2011; Khalil and Fathy, 2008; Corredor, 2013)**. Other researchers used multiple regression equations with different predictor variables (weather parameters) for estimating the daily global radiation such as: clearness index, mean relative sunshine duration (S/S_0), mean daily maximum temperature (T_{max}), mean daily relative humidity (Rh), mean daily rainfall (R), mean daily temperature ($\overline{T}$), ratio of maximum and minimum daily temperature and other weather parameters **(Falayi et al., 2008; Augustine and Nnabuchi, 2009; Ituen et al., 2012; Habbib, 2011)**. These researchers depend in their studies on different changeable predictors. However, using multiple regression models for estimating the daily global radiation give more accurate results than other equations that depends on one variable under condition of presence the mean relative sunshine duration parameter. So, to avoid damage from high UV exposures, both acute and chronic, people should limit their exposure to solar radiation by using protective measures **(Allinson et al., 2012)**. In 2002, the concept of the UVI was expanded as a public awareness tool to help the public conceptualize the amount of harmful UV radiation and to alert people to the need for sun protection measures **(WHO, 2002).** After 10 years of use, a systematic review of the effectiveness of the UVI revealed that the UVI has raised public awareness of UV exposure to some extent, but that it has not significantly improved sun protection practices **(Italia and Rehfuess, 2012)**.

Ionizing radiation, particularly X-ray and those emitted by radioactive substances, play a vital role in medicine, both in diagnosing and treating diseases **(Calabreseet al., 2014)**. On the other side, ionizing radiation is known as one of the detrimental factors in the work environment that can cause serious, irreversible and irreparable damages in professional radiation workers, but the effects of low doses on human health has not been completely known **(Klucinski et al., 2014)**. Considering and following up the health of persons who are occupationally exposed to long-term, low levels of ionizing radiation is of great importance. Basic studies on the biological response to radiation at low doses are considered a research priority in order to better understand the occupational risks associated with working in radiation departments with the possible development of long-term health effects **(Heydarheydari et al., 2016)**.However, radiation may damage various cellular components including DNA, directly (molecule ionization) or indirectly (reactive oxygen species production). Irradiated cells protect themselves by many innate defense mechanisms such as removal of oxidative stress and damaged cells, and DNA repair. Remained damages of cells may cause tissue/organ dysfunction and malignant diseases. For radiation protection, the biological effects of radiation are conventionally categorized into two broad classes: stochastic and deterministic effects (or recently termed tissue reactions) **(Seong et al., 2016)**.***Stochastic effects*** have probability of occurrence depending on the irradiated doses without threshold. These effects can occur by chance and consist primarily of cancer and genetic effects such as inherited mutations. It often shows up years after exposure. In addition, because they can occur in individuals under background radiation levels without exposure, it can never be determined that an occurrence of these effects was due to a specific exposure **(Mettler, 2012)**.***Deterministic effects*** (or non-stochastic effects) are malfunctions of organs by irradiation at more than threshold. These effects do not exist below their threshold doses, for example, skin burns, cataracts, cardiovascular disease, intestinal damage, and hemopoietic system and central nervous system failure **(Kadhim et al., 2013)**. Recent ICRP report referred to deterministic effects as tissue reactions because it was recognized that these effects are not decided at the moment of irradiation and can be modified through various biological responses **(ICRP, 2012)**. This simplistic classification is not absolute. Deterministic effects can occur as a result from the loss of normally functioning large number of critical cells caused by stochastic killing of irradiated individual cells **(Seong et al., 2016)**.

Over the last several years, there was a trend to investigate the biological effects of the radiation using hematological, biochemical, and cytogenetic parameters **(Ossetrova et al., 2010)**.These investigations have demonstrated that stochastic effects may appear after the exposure to low level radiation **(Elgazzar and Kazem, 2015)**.Deterministic effects are well-known and often need higher radiation doses than received by medical professionals (MPs) **(Yang et al., 1995)**.Therefore the concern and unawareness of MPs are related to the stochastic effects of long-term exposure to low-dose radiation. The risk of stochastic effects, such as cancer, increase by dose without threshold **(Muirhead et al., 2009; Venneri et al., 2009)**.Long-term exposure to low doses of ionizing radiation can affect proliferating cells **(Fliedner et al., 2012)** and tissues. The effect of radiation on hematopoietic and immune system **(Hrycek et al., 2002; UNSCEAR, 2012)** suggest that, long-term effects can disturb immunity of MPs by suppressing or stimulating the immune system and may induce various hematological diseases **(Roguin et al., 2012; Venneri et al., 2009)**.However, the biological effects of chronic low-dose radiation on human health are complex and have not been well established. It seems that, hematological parameters survey could not be a reliable test as the biological indicator of long term exposure to very low dose of radiation exposure in medical professionals which their physical dosimetry values are lower than dose limits **(Shafiee et al., 2016)**.Additionally, all the workers occupationally exposed showed an increase in DNA fragmentation after the workday. The amount of radiation in all three services is different, in Nuclear Medicine and Radiotherapy the workers showed a greater monthly dose of exposure and greater DNA damage than the Radiology workers. Most of the DNA damage detected by the comet assay is repaired; however a part of it may result in stable chromosomal rearrangements that may represent a long-term health risk. It is important to sensitize exposed workers on their responsibility of working with radiation and the improvement of the hospital safety practices **(Martínez et al., 2010)**.Fortunately, Low-level radiation exposure is generally considered to be less than the dose that produces immediate or short-term observable biological effects. In humans, low-LET gamma or X-radiation doses of less than 0.5 Gy do not produce prodromal symptoms or the hematopoietic subsyndrome; however, recent studies suggest that low-level radiation exposure does increase the probability that delayed effects will occur **(Hall et al., 2012; Joiner and van der Kogel, 2009)**. There are four types of delayed radiation effects: (1) somatic, (2) genetic, (3) teratogenic, and (4) transgenerational. Irradiation enhances the naturally occurring frequency of the specific effect, and in some cases produces the observable endpoint by a process different than that of a natural process. Certain biological responses have such low thresholds that they are statistically indistinguishable, in many cases, from normal incidence **(Joiner and van der Kogel, 2009;Miller et al., in press)**.

The Aim:-

The study clarifies the late and low level effects of ionizing radiation on health and recognizes the adverse effects of excessive solar radiation on skin, eyes and the immune system. It also outlines new approaches on how to improve the effectiveness of the UVI as a public awareness tool toward encouraging sun protection behavior aiming to reach a simplified estimation method and accurate predictive results for daily H and UVI_{max}.

Materials and Methods:-

In the current study, UVI_{max} is modeled for forecasting its daily value. The statistical prediction model is based on two independent variables (predictor variables) for constructing the linear multiple regression equation. The first predictor is daily clear sky global solar radiation on a horizontal surface (H) and the second predictor is daily maximum temperature (T_{max}). These model predictors are considered more accurate effective for UVI_{max}forecasting results than other weather parameters. Additionally, model is developed with multiple regression equation than other researchers to predict the daily global solar radiation future time (H). The developed multiple regression models based on three predictors. These independent variables are: monthly average day length (S_0), monthly average cosine solar zenith angle at mid-time between sunrise and solar noon ($\cos(\theta_{ZMT})$) and monthly average daily temperature $(\bar{T})$ .Two predictors are calculated (S_0 & $\cos(\theta_{ZMT})$) and one predictor is measured $(\bar{T})$. This model is considered a simplified statistical approach because it depends on two monthly constant predictors (S_0&$\cos(\theta_{ZMT})$) and one daily changeable predictor $(\bar{T})$.

The material data of monthly averaged clear sky global radiation on a horizontal surface ($kWh/m^2/day$) and monthly average air mean and maximum temperature at 10m above the earth surface $(\bar{T} \,\&\, \bar{T}_{\max})$ (degrees Celsius) is obtained from NASA meteorology **(NASA., 2016).** The data covered a period of 22 years (1983 – 2005) for Sharm El-Shiekh in Egypt at Latitude 27.912^o and longitude 34.33^o. UVI data is obtained from Weather2Travel climate guides **[weather2travel]**. The suggested modified empirical model ofclear sky global solar radiation has been estimated on the basis of measurements of monthly averaged clear sky global radiation on a horizontal surface and monthly average air mean temperature for Sharm El-Shiekh. Also, the empirical model based on calculation of monthly mean daily extraterrestrial radiation, maximum possible sunshine duration and monthly average cosine solar zenith angle at mid-time between sunrise and solar noon.

Developed empirical modelto estimate the daily global radiation (*H*):-

The devolved model for estimating the daily global radiation based on three independent variables (predictor variable) and one dependent variable (response variable). The response variable is the variable to be predictable $\bar{H}/\bar{H}_0$ and the three-predictor variables are S_0, $\cos(\theta_{ZMT})$ and $\bar{T}$.

The following modification empirical model is used to estimate the daily global radiation

$$\frac{\bar{H}}{\bar{H}_0} = 0.6857 - 0.010306(S_0) + 0.42213(\cos(\theta_{ZMT})) - 0.002947(\bar{T}) \tag{1}$$

$$\bar{H}_{calculated} = \left(0.6857 - 0.010306(S_0) + 0.42213(\cos(\theta_{ZMT})) - 0.002947(\bar{T})\right)\bar{H}_0$$

where, $\frac{\bar{H}}{\bar{H}_0}$ is clearness index, $\bar{H}$ is monthly mean daily clear sky global solar radiation on a horizontal surface, $\bar{H}_0$ is monthly mean daily extraterrestrial radiation KW/m^2, S_0 is monthly average day length, $\cos(\theta_{ZMT})$ is monthly average cosine solar zenith angle at mid-time between sunrise and solar noon and $\bar{T}$ is monthly average daily temperature. The values of the monthly average daily extraterrestrial radiation ($\bar{H}_0$) can be calculated from equation 2 **(Duffie and Beckman, 2013)**.

$$\bar{H}_0 = \frac{24}{\pi} I_{SC} E_0 \left[\cos\phi \cos\delta \sin w_s + \frac{\pi w_s}{180} \sin\phi \sin\delta \right] \quad (2)$$

$$E_0 = 1 + 0.033 \cos\left[\frac{360 d_n}{365} \right]$$

where, I_{SC} is the solar constant (=1.367 KWm^{-2}), ϕ is the latitude of the site, δ is the solar declination, w_s is the mean sunrise hour angle for the given month, and $d_n$is the number of days of the year starting from the first of January (the Julian day number) . The solar declination (δ) and the mean sunrise hour angle (w_s) can be calculated by the following equations:

$$\delta = 23.45 \sin\left[360 \frac{(d_n + 284)}{365} \right]$$

$$w_s = \cos^{-1}\left(-\tan\phi \tan\delta \right)$$

The maximum possible sunshine duration (S_0) (or monthly average day length) which is related to w_s, can be computed by using the following equation:

$$S_0 = \frac{2}{15} w_s \quad (3)$$

Monthly average cosine solar zenith angle at mid-time between sunrise and solar noon is calculated according the following formula **(NASA., 2016)**:

$$\cos(\theta_{ZMT}) = f + g[(g - f) / 2g]^{½} \quad (4)$$

where,

$f = \sin(\phi)\sin(\delta)$, $g = \cos(\phi)\cos(\delta)$

Monthly average daily mean temperature ($\bar{T}$) is calculated as follows:

$$\bar{T} = \frac{(T_{maximum} + T_{minimum})}{2} \quad (5)$$

Empirical modelto estimate the daily maximum ultraviolet index(UVI$_{max}$):-

The statistical estimation modelof daily ultraviolet index is based on two independent variables for constructing the linear multiple regression equation. The first predictor is the monthly mean daily clear sky global solar radiation on a horizontal surface $(\bar{H})$ and the second predictor is monthly average maximum temperature ($\bar{T}_{max}$).

UVI_{max} = -4.5146+ 1.4178($\bar{H}_{calculated}$) + 0.12697($\bar{T}_{max}$) (6)

H and T_{max} are considered more accurate effective for UVI_{max} forecasting results than other weather parameters.

Statistical Evaluation:-

There are numerous works in literature which deal with the assessment and comparison of monthly mean daily solar radiation estimation models. The most popular statistical parameters are the mean bias error (MBE) and the root mean square error (RMSE) (**Muzathik et al., 2011**). In this study, to evaluate the accuracy of the estimated data, from the models described above, the following statistical tests are used, MBE, RMSE, mean absolute percentage error (MAPE) **(Sivamadhavi and Selvaraj, 2012; Corredor, 2013)** and coefficient of correlation (R). The evaluation accuracy is based on the low error value and the high correlation coefficient value.

$$MBE = \frac{\sum_{i=1}^{n}\left((\bar{H}_{i,caculated} - \bar{H}_{i,measured}\right)}{n} \quad , \quad RMSE = \sqrt{\frac{\sum_{i=1}^{n}\left((\bar{H}_{i,caculated} - \bar{H}_{i,measured}\right)^2}{n}}$$

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{\bar{H}_{i,measured} - \bar{H}_{i,caculated}}{\bar{H}_{i,measured}}\right| * 100 \quad ,$$

$$R = \frac{\sum_{i=1}^{n}(\bar{H}_{i,caculated} - \bar{H}_{caculated})(\bar{H}_{i,measured} - \bar{H}_{measured})}{\sqrt{\left(\sum_{i=1}^{n}(\bar{H}_{i,caculated} - \bar{H}_{caculated})^2\right)\left(\sum_{i=1}^{n}(\bar{H}_{i,measured} - \bar{H}_{measured})^2\right)}}$$

Results:-

Devolved empirical equation for prediction of daily global solar radiation (H):-

The various meteorological data are related to global solar radiation (H). Empirical model is developed to estimate the daily global radiation. Multiple linear repression analysis of four parameters is employed to estimate the daily global solar radiation ($\bar{H}/\bar{H}_0$, S_0, $\cos(\theta_{ZMT})$ and $\bar{T}$).

The following modification empirical model is devised for global solar radiation estimation.

$$\frac{\bar{H}}{\bar{H}_0} = 0.6857 - 0.010306(S_0) + 0.42213(\cos(\theta_{ZMT})) - 0.002947(\bar{T})$$

$$\bar{H}_{calculated} = \left(0.6857 - 0.010306(S_0) + 0.42213(\cos(\theta_{ZMT})) - 0.002947(\bar{T})\right)\bar{H}_0$$

The calculated values for $\bar{H}_0$, $\bar{H}/\bar{H}_0$, S_0, $\cos(\theta_{ZMT})$, $\bar{T}$ and $\bar{H}_{calculated}$ for Sharm El-Sheikh are presented in Table 1.

Table 1:-Meteorological data and clear sky global solar radiation for Sharm El-Sheikh

MONTH	$\bar{H}_{measured}$ (KW/m²/ day)	$\bar{H}_0$ (KW/m²/ day)	$\bar{H}_{meas}/\bar{H}_0$	S_0	$\cos(\theta_{ZMT})$	$\bar{T}$	$\bar{H}_{calc}/\bar{H}_0$	$\bar{H}_{calculated}$ (KW/m²/ day)
JAN	**4.55**	6.2563	0.72727	10.4467	0.47335	15.8	0.73129	**4.5751**
FEB	**5.58**	7.4431	0.74969	11.0364	0.53653	16.5	0.74982	**5.5810**
MAR	**6.88**	8.9678	0.76719	11.8304	0.61038	19.6	0.76368	**6.8485**
APR	**7.88**	10.3083	0.76443	12.6801	0.66447	24.0	0.76478	**7.8836**
MAY	**8.34**	11.0896	0.75206	13.3882	0.68588	27.7	0.75562	**8.3795**
JUN	**8.53**	11.3487	0.75163	13.7394	0.68930	30.0	0.74667	**8.4736**
JUL	**8.30**	11.1865	0.74197	13.5742	0.68823	31.3	0.74409	**8.3237**
AUG	**7.84**	10.5560	0.74270	12.9619	0.67545	31.4	0.74471	**7.8612**
SEPT	**6.98**	9.3964	0.74284	12.1415	0.63373	30.1	0.73938	**6.9475**
OCT	**5.69**	7.8727	0.72275	11.2938	0.56229	26.5	0.72857	**5.7358**
NOV	**4.72**	6.5046	0.72564	10.5924	0.48926	21.8	0.71882	**4.6757**
DEC	**4.22**	5.8725	0.71861	10.2591	0.45275	17.6	0.71922	**4.2236**

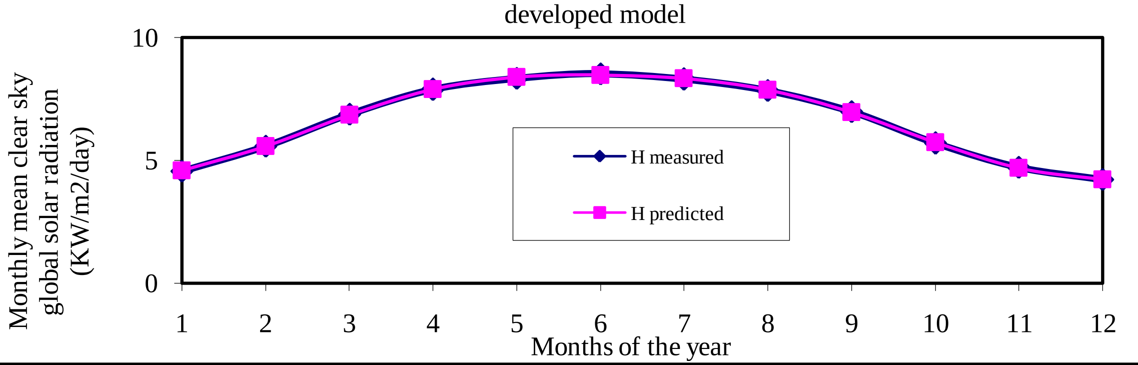
A number of linear multiple regression equations (7-10) were developed by other researchers to predict the relationship between global solar radiations with one or more combinations of weather parameters. Some researchers used different weather parameters such as: clearness index, The mean relative sunshine duration (*S/S_0*), mean daily maximum temperature (*T_{max}*), mean daily relative humidity (*Rh*), mean daily rainfall (*R*), mean daily temperature ($\bar{T}$), ratio of maximum and minimum daily temperature and other weather parameters. The suggested modified multiple regression model (eqn. 1) is developed using weather parameters different than that other weather parameters previously used. The suggested developed model and some researchers-developed models are tested for our and their applicability to predict the global solar radiation for State of Sharm El-Sheikh. The suggested developed model is considered a simplified statistical approach because it depends on constant predictors ($\bar{H}_0$, S_0 and $\cos(\theta_{ZMT})$) and one inconstant predictor ($\bar{T}$). The constant predictors are determinate according to its corresponding month (from Table 1). All constant predictors are calculated and the changeable predictor is measured. Table 2 shows some statistical indicators (R, MBE, RMSE and MAPE) for comparing the suggested developed model with some linear multiple regression models.

Table 2: Equations with regression and statistical indicators of accuracy

Equations	source	R	MBE	RMSE	MAPE
$\frac{\bar{H}}{\bar{H}_0}=0.94736+0.06068(S/S_0)-0.0407(T_{mini}/T_{maxi})-0.4528(Rh/100)-0.00299(\bar{T})$ (7)	**(Falayi, 2008; Habbib, 2011)**	0.998	-0.0005	0.0586	0.729
$\frac{\bar{H}}{\bar{H}_0}=0.9697+0.0519(S/S_0)-0.00342(T_{maxi})-0.495(Rh/100)$ (8)	**(Ituen, 2012)**	0.999	-0.0021	0.0600	0.732
$\frac{\bar{H}}{\bar{H}_0}=0.956-0.5672(T_{mini}/T_{maxi})+0.0054(T_{maxi})$ (9)	**(Okunda-miya, 2011)**	0.999	-0.0032	0.0652	0.787
$\frac{\bar{H}}{\bar{H}_0}=1.582+0.05963(S/S_0)-0.5407(T_{average}/T_{maxi})-0.125(\ln(Rh))$ (10)	**(Adhika-ri, 2013)**	0.999	-0.0011	0.0687	0.832
$\frac{\bar{H}}{\bar{H}_0}=0.6857-0.010306(S_0)+0.42213(\cos(\theta_{ZMT}))-0.002947(\bar{T})$		**0.9998**	**-0.000098**	**0.0323**	**0.422**

The results obtained show a remarkable agreement between the measured and the predicted values using different linear multiple regression models. The empirical developed model under study (eqn. 1) gives the best accuracy and more reliable results than other researchers' models (eqns. 7-10). The accuracy tests indicate that the error rate is reduced nearly by 40-50% in favor of our developed model. Therefore, the suggested developed model is preferred to use for prediction of global solar radiation on horizontal surface for Sharm El-Sheikh. Figure 1 shows comparison between the measured and predicted global solar radiation using the suggested empirical developed model. It is clear from the figure that there is an excellent correlation exists between the measured and predicted global solar radiation. However, the predicted global solar radiation overlaps the measured global solar radiation in all months of the year.

Fig. 1:- Comparison between the measured and predicted global solar radiation for developed model



To predict the daily global solar radiation in Sharm El-Sheikh, substitute S_0 and $\cos(\theta_{ZMT})$ values in the developed empirical equation according to the corresponding month for this predictable day. $\bar{T}$ is calculated from daily changing maximum and minimum temperature. For example, to predict daily global solar radiation of few days for some months, substitute the values of S_0, $\cos(\theta_{ZMT})$, $\bar{H}_0$ (from Table 1) and $\bar{T}$ (from eqn. 5) in equation 1. The results are presented in Table 3.

Table 3:-Some calculated values of daily global solar radiation.

Date	$\bar{H}_0$	S_0	$\cos(\theta_{ZMT})$	$\bar{T}$	$\bar{H}_{calc}/\bar{H}_0$	$H_{calculated}$ KW/m²/ day
16-6-2015	11.34866	13.73937	0.689297	(35+26)/2=30.5	0.745201	**8.457026**
19-6-2015	11.34866	13.73937	0.689297	(40+29)/2=34.5	0.733414	**8.323262**
28-6-2015	11.34866	13.73937	0.689297	(36+27)/2=31.5	0.742254	**8.423585**
03-7-2015	11.18652	13.57424	0.68823	(34+27)/2=30.5	0.746452	**8.350196**
26-7-2015	11.18652	13.57424	0.68823	(40+28)/2 = 34	0.736138	**8.234825**
29-7-2015	11.18652	13.57424	0.68823	(41+29)/2 = 35	0.733192	**8.201861**
06-8-2015	10.55604	12.96194	0.67545	(40+31)/2 = 35.5	0.732636	**7.733736**
09-8-2015	10.55604	12.96194	0.67545	(43+33)/2 = 38	0.725269	**7.655973**
13-8-2015	10.55604	12.96194	0.67545	(43+32)/2 = 37.5	0.726743	**7.671525**

Table 3 shows that in the month range June-August (Fig.1) the global solar radiation value decrease with the increase in average temperature value. The given month range belongs to the maximum value in Fig. 1. The choice of the month range June-August (summer) is considered in this work because the effect of UVI is maximum. Moreover, the estimated high global solar radiation of the summer months is required for detailed study to get the maximum benefits of solar energy for electric power production.

Empirical equation for forecasting daily ultraviolet index (UVI):-

In this section, the strong relationship between H, T_{max}(as independent variable) and UVI (as dependent variable) is illustrated by using the linear multiple regression equation which relating to these three variables. Two linear multiple regression equations are compared for attempt to deduce the best of them. The first equation (eqn. 6) is based on $\bar{H}_{calculated}$ and $\bar{T}_{max}$. The second equation (eqn. 11) is based on $\bar{H}_{measured}$ & $\bar{T}_{max}$.

UVI_{max}predicted = -4.5146+ 1.4178($\bar{H}_{calculated}$) + 0.12697($\bar{T}_{max}$)

UVI_{max} predicted = -4.5156+ 1.4123($\bar{H}_{measured}$) + 0.12823($\bar{T}_{max}$)(11)

The results of estimated UVI_{max} according to equations 6 and 11 are shown in Table 4.

Table 4:-Meteorological data and ultraviolet index for Sharm El-Sheikh

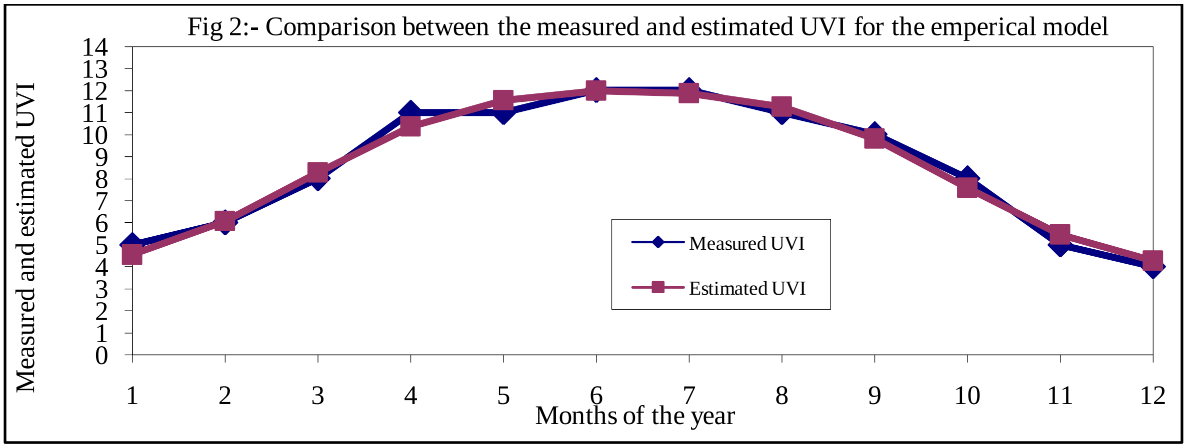
MONTH	(UVI_{max}) measured	$\bar{H}_{calculated}$ (KW/m²/day)	T_{max}	estimated (UVI_{max}) from $\bar{H}_{calculated}$	$\bar{H}_{measured}$ (KW/m²/day)	estimated (UVI_{max}) from $\bar{H}_{measured}$
JAN	**5**	4.5751	20.2	4.537	4.55	**4.500**
FEB	**6**	5.5810	21.0	6.064	5.58	**6.057**
MAR	**8**	6.8485	24.3	8.281	6.88	**8.317**
APR	**11**	7.8836	29.2	10.37	7.88	**10.36**
MAY	**11**	8.3795	33.0	11.56	8.34	**11.49**
JAN	**12**	8.4736	35.3	11.98	8.53	**12.06**
JUL	**12**	8.3237	36.1	11.87	8.30	**11.84**
AUG	**11**	7.8612	36.4	11.25	7.84	**11.22**
SEPT	**10**	6.9475	35.2	9.805	6.98	**9.856**
OCT	**8**	5.7358	31.2	7.580	5.69	**7.521**
NOV	**5**	4.6757	26.3	5.454	4.72	**5.523**
DEC	4	4.2236	21.9	4.254	4.22	**4.253**

The accuracy indicators, R, MSE, RMSE and MAPE, are used for measuring the powerful of empirical forecasting models and for illustrating the best estimator model, which gives the best prediction performance results. Table 5 displays the results of the accuracy indicators values.

Table 5:-Statistical indicators of accuracy

Accuracy Indicators	R	MSE	RMSE	MAPE
UVI_{max} predicted from $\bar{H}_{calculated}$	0.9919	0.131	0.362	0.042342
UVI_{max} predicted from $\bar{H}_{measured}$	0.9918	0.140	0.374	0.044359

According to the accuracy indicators, there are slightly differences between the results of the two models. The results show that, equation 6 gives the best prediction performance results comparing with equation 11. Therefore, using equation 6 is recommended. The value of *H* is calculated according to equation 1 and the value of $T_{max}$is determinate according to its daily changeable value. Figure 2 shows comparison between the measured and estimated UVI_{max} using the empirical model. It is clear from that figure that there is a very good correlation exists between the measured and estimated UVI.\



For example, to estimate the value of $UVI_{max}$of the same days in Table 3, substitute the values of $H_{calculated}$ and T_{max} (from Table 3) in equation 6. The results of UVI_{max} values are presented in Table 6.

Table 6:-Some estimated values of daily UVI_{max}

Date	$H_{calculated}$	T_{max}	Estimated UVI_{max}
16-6-2015	8.457026	35	**11.92**
19-6-2015	8.323262	40	**12.36**
28-6-2015	8.423585	36	**12.00**
03-7-2015	8.350196	34	**11.64**
26-7-2015	8.234825	40	**12.24**
29-7-2015	8.201861	41	**12.32**
06-8-2015	7.733736	40	**11.53**
09-8-2015	7.655973	43	**11.80**
13-8-2015	7.671525	43	**11.82**

Table 6 shows that the value of UVI_{max} increases with the increase in the value of maximum temperature, so that the increase is linked to the high values of H for each day in that month. As well, UVI_{max} is extremely high in Jun, July and August. Therefore, estimate of $UVI_{max}$and its health protection are recommended in those months of the year.

The daily UV dose (DUVD) is calculated as an integral of UV index over the daylight time:-

$$DUVD = \int_{T_0}^{T_{N+!}} UVI(t)dt$$

$T_o$is the sunrise time and T_{N+1} is the sunset time.

The calculations are performed again using the trapezoid rule that results in the following formula:-

$$DUVD = \frac{1}{2}\sum_{j=0}^{N}(UVI_j + UVI_{j+1}) \cdot (T_{j+1} - T_j)$$

The daily UV dose is in UV Index hours (UVI h) if the units of T_j are hours. To convert UVI h units to kJ/m^2, units that are commonly used to express DUVD, the result from the last equation have to be multiplied by the factor: 0.09=25*3.6/1000 **(Kiedron et al., 2007).**

Discussion:-

The increase in the amount of solar ultraviolet (UV) light that reaches the earth is considered to be responsible for the worldwide increase in skin cancer and considered as the main etiological factor **(Rivas et al., 2015)**. It has been reported that excessive levels of UVA and UVB light have multiple effects, which can be harmful to humans. There is a steady increase in the incidence of skin cancer in Africa, most probably due to the high levels of UV light and the latitude to which individuals are exposed throughout the year, as well as the accumulative effect of this type of radiation on the skin **(Rivas et al., 2015)**. At the time of developing the UVI, the less energetic UVA (315-400 nm), which is 1,000-fold less efficiently absorbed by DNA than UVB, was believed to play little or no role in skin carcinogenesis as only UVB (280-315 nm) had been shown to damage DNA directly. On the basis of data, in 2009, the International Agency for Research on Cancer (IARC) classified UVA, both from sunlight and tanning devices, as carcinogenic to humans **(IARC, 2012)**. Though less directly damaging to DNA than UVB, UVA is much more abundant in natural light. There is now convincing in vitro and in vivo evidence that UVA is able to cause damage to a variety of biomolecules via photosensitizer mediated processes, leading to oxidative damage to lipids and protein, and can create a number of molecules, including pyrimidine dimers and base oxidation products associated with DNA strand breaks **(Ridley et al., 2009**). The genotoxic effects of solar UV radiation may therefore derive from both UVB and UVA with the efficiency of DNA repair pathways such as base excision repair and nucleotide excision repair playing an important modulating role in determining the spectrum of mutations produced **(Ridley et al., 2009; Ikehata and Ono, 2011)**. Additionally, The facts that UVA is more penetrating than UVB, reaching keratinocytic stem cells and melanocytes of the basal layer, and also substantially contributes to local immunosuppression **(Halliday et al., 2011)** provide a further layer of complexity in understanding the contribution of UVA to skin carcinogenesis **(Allinson et al., 2012)**.

The UVI refers to the daily maximum effective irradiance and serves as an indicator of the impact of UV-radiation on erythema (sunburn), an acute skin effect that is closely related to the potential for chronic sun-induced skin damage like skin cancer and photoaging **(Allinson et al., 2012)**. The current UVI formula is weighted around the clinical finding of erythema, which is primarily UVB associated. Moreover, the use of erythema as a surrogate for cancer risk is supported by consistent positive associations between sunburn and both melanoma and non-melanoma skin cancer **(Dennis et al., 2008)**. Epidemiologic studies, however, are not able to quantify skin cancer risk at low levels of sun exposure (UVI 1-3) and cannot distinguish between the specific impact of UVA and UVB radiation. Outdoors, humans are virtually always exposed to UVA and UVB simultaneously, whose intensities vary broadly in parallel. The UVA-UVB ratio depends on the solar zenith angle and thus on the latitude, altitude, time of day, and season, but these variations are too small to capture as input parameters in epidemiologic studies. Thus, although the contribution of UVA to carcinogenesis has likely been underestimated in the past, minor modifications of the action spectrum to take this into account are not expected to have a significant impact on the UVI. The UVI was developed as a tool to conceptualize the amount of harmful radiation and to encourage the general public to use sun protection, and it is recommended to be integrated with broader public health approaches (Table 7) **(WHO, 2002)**.

Table 7:-UV Index and the corresponding exposure level as categorized by the World Health Organization (WHO)

UV Index	0–2	3-5	6-7	8-10	≥11
Exposure level	Low	Moderate	High	Very high	Extreme

Studies examining the impact of the UVI on knowledge, attitudes, sun protection behavior and sun exposure generally showed no effect **(Italia and Rehfuess, 2012)**. This suggests that the UVI can raise risk awareness to some extent, but given low levels of understanding in the general population, its potential as a tool to change behavior is limited. Nevertheless, the UVI can indicate usefully when sun protection is required, and several studies have shown population demand for UVI information **(Wester and Paulsson, 2000; Börner et al., 2010; Bulliard and Reeder, 2001)**. As awareness about skin cancer prevention and vitamin D increases, so will the interest of the general population in the UVI. For this reason, promotion of the UVI is encouraged. The possible improvements in the utility of the UVI as a public awareness tool are discussed and agreed. It was confirmed that sun protection messages promoted at a UVI of 3 and above are of high public health relevance toward reducing skin cancer incidence and do not conflict with other health messages, especially regarding vitamin D and outdoor physical activities. There is currently insufficient evidence about the quantitative relationship of sun exposure, vitamin D, and human health to include vitamin D considerations in sun protection recommendations. The UVI continues to be a useful tool to estimate risk from solar exposure. However, the impact of the UVI on sun protection behavior is currently very limited, and primary research is needed to improve the effectiveness of the UVI as a public awareness tool. Additionally, well conducted studies are needed on the most effective strategies for using the UVI as part of sun protection efforts. On the other hand, the final goal of changing sun protection behavior in the population might be reached by developing health promotion campaigns that account for personal determinants, such as attitudes, self-efficacy, and self-affirmation **(Allinson et al., 2012)**.

Fortunately, the UV Dose (UVD) is directly related to some health effect on humans. A 50% increase in erythemal UVD would therefore increase the rate at which the skin reddens by 50% **(Wiegant et al., 2016)**. However, **Hatfield et al., (2009)** found statistical relations between exceedance of threshold UVI values and cancer incidence rates by investigating the relation between UV exposure and non-melanoma skin cancer using a statistical model. On the other hand, Vitamin D production in the skin is directly related to UV irradiance weighted by the vitamin D action spectrum. Vitamin D may have beneficial effects regarding cancer incidence and survival rates **(Lim et al., 2006; Garland et al., 2006)**. **Kelly et al., (2016)** study the vitamin D thresholds. They studied plasma vitamin D (25OHD) in blood samples in relation to a cumulative weighted vitamin D UVD.The vitamin D production is directly related to the UVD (unlike cancer to UVI, which is statistically related). The UVI threshold of 7 is relevant for skin cancer. Ozone concentrations (in the stratosphere) do not directly relate to any health effects, whereas the UVI and UVD do. Studying the health effects in these regions is the main interest, as this is the primary reason for translating ozone to surface UV irradiance. Interpretation of the results regarding skin cancer incidence and vitamin D can still be expanded, although this is largely dependent on how scientists in the field of medicine quantify the effect of UV irradiance on humans **(Wiegant et al., 2016)**. However, **Juzeniene et al., (2014)**, found a direct relation between cancer incidence rates and UVD using sigmoidal curves.

Professional radiation workers are occupationally exposed to long-term low levels of ionizing radiation. Occupational health hazards from radiation exposure, in a large occupational segment of the population, are of special concern. The effective annual dose ranged from 0.05 to 6.84 mSv; radiation workers had a median exposure of 0.68±1.58 mSv/year. These doses, although below maximal permissible limits set by the International Commission of Radiation Protection (ICRP), can have clear biological effects **(Heydarheydari et al., 2016)**. Fortunately, the late effects of ionizing radiation can be divided into three major groups: **Somaticdamage** ranges from fibrosis and necrosis of individual organs to cataracts and cancer **(O'Sullivan et al., 2003; Stroian et al., 2008)**. It can result from somatic mutations and accumulated damage, and include impaired circulation, necrosis, fibrosis of skin and muscle tissue, loss of hair, loss of taste, impaired bone growth, susceptibility to disease, immunodeficiency, aplastic anemia, cataracts, and increased incidence of cancer **(Joiner and van der Kogel, 2009)** Radiation-induced fibrosis (RIF) is one of the most predominant long-term adverse effects of ionizing radiation **(O'Sullivan et al., 2003; Stroian et al., 2008)**.Typically, fibrotic response occurs due to the progressive onset of extra cellular matrix (ECM) deposition from stromal tissue such as lung, liver, kidney, and intestine. Chronic deposition leads to loss of elasticity and muscular dysfunction or atrophy in extreme cases. The severity of fibrosis depends on radiation dose, quality of radiation, and dose rate. Fibrosis may be accompanied by epilation, loss of vascularity, and even necrosis of the tissue **(O 'Sullivan et al., 2003)**. The lens tissue of the eye is particularly radiosensitive and radiation exposure can increase its opacity. Radiation cataractogenesis is the most common delayed radiation injury and is thought to result from damage to the anterior equatorial cells of the lens's epithelial tissue **(O'Sullivan et al., 2003; Stroian et al., 2008)**. Most somatic effects require high threshold doses of radiation; cancer is the main health concern after exposure to low-level radiation. The three most common radiation-induced malignancies are leukemia, breast cancer, and thyroid cancer. The latency periods for the detection of cancer after radiation exposure range from 2 years for leukemia to 30 to 40 years for some solid tumors. On the other hand, the acute effects of radiation exposure on skin are well known and result in severe skin burns **(Miller et al., in press)**. However, low levels of chronic radiation to skin have been observed as well. The accompanying erythema, which resembled a burn, was painless; but, chronic radiation dermatitis following repeated exposure is usually extremely painful. Five progressive categories of radiation damage are observed in skin: (1) erythema, (2) transepithelial injury (moist desquamation), (3) ulceration, (4) necrosis, and (5) skin cancer. Radiation-induced erythema occurs in two stages: (1) mild initial erythema, usually appearing within minutes or hours on the first day after irradiation (occurring earlier with higher doses), and (2) the main erythema, appearing at 2 to 3 weeks and persisting for longer periods. In some cases, a third erythema may occur at 6 weeks. Radiation-induced erythema is a threshold phenomenon. Early erythema arises from the release of mediators and from increased capillary dilation and permeability. It is equivalent to a first-degree burn or mild sunburn, subsiding within 2 or 3 days. Although indomethacin and other prostaglandin-synthesis inhibitors have been used topically to prevent or reduce erythema caused by sunburn or ultraviolet light, they have not been widely used to treat radiation induced erythema. The second onset of erythema is attributed to impaired circulation in the arterioles, producing inflammation and edemas and accompanied by dry desquamation of the epidermal corneocytes. Upper cells are sloughed or abraded off, exposing cells that are not completely keratinized. Cell death and moist desquamation ensue. Both dry and wet desquamation occur about 1 to 4 weeks after irradiation. Regeneration of the stratum corneum requires 2 months to 4 years, and this regenerated tissue will be more sensitive to other skin-damaging agents. The new skin may be thinner than the original, with greater sensitivity to touch and pain. Reduction or loss of the dermal ridges making up the fingerprint has occurred from large or chronic exposures **(Miller et al., in press)**. Fortunately, skin cancers are common in those using radiation equipment, although the incidence has decreased due to increased safety standards **(Hall et al., 2012; Miller, 2007)**. In general, radiation skin cancers are readily diagnosed and treated at any early stage of development and maintain a high rate of curability **(Miller et al., in press)**.

Genetic or hereditary effects are the second category of low-level or late effects of radiation. It is estimated that 5 to 65 additional genetic disorders will occur in the next generation for every million individuals receiving 0.01 Gy of gamma or low-LET radiation **(Hall et al., 2012; Joiner and van der Kogel, 2009; Miller, 2007)**. These disorders will be mainly autosomal dominant and gender linked. If each succeeding generation were to receive an additional 0.01 Gy of radiation, equilibrium would be reached in the gene pool, and an average increase of 60 to 1,100 genetic disorders per million individuals would be observed in the population. This would result in a 1.5% increase in the overall incidence of genetic disorders. The normal incidence of genetic disorders in the population is 1 in 10 **(Miller et al., in press)**.However, genetically induced malformations, cancers, and numerous other health effects in the children of populations who were exposed to low doses of ionizing radiation have been unequivocally demonstrated in scientific investigations **(Schmitz-Feuerhake et al., 2016)**.The third category of late radiation damage is **teratogenic** effects. The primary teratogenic somatic effects seen in humans exposed in utero are microencephaly, intellectual disability, and growth retardation. These effects have been observed with an increased incidence in the atomic bomb survivors exposed in utero to doses of less than 0.10 Gy, although a neutron component may have enhanced the radiation effectiveness. In general, thresholds exist for the induction of birth defects by radiation, and effects below 0.10 Gy are negligible. The normal incidence of birth defects is 1 in 10 live births. One concern for low-level exposure to ionizing radiation in utero is the increased incidence of cancer in childhood. An estimated 25 additional cancer deaths are predicted for every million children receiving 1 cGy of radiation in utero. Preconceptional parental exposures leading to transgenerational effects have recently become a concern. The human data are inconclusive and controversial, so no risk estimates have been established. Further studies in epidemiology and with animal models will provide guidance **(Miller et al., in press)**.

Conclusion and Recommendation:-

Empirical model is developed to estimate the daily clear sky global radiation (H). Multiple linear repression models of four variables are employed to estimate H. According to statistical evaluation, the predicted clear sky global solar radiation overlaps the measured clear sky global solar radiation in all months of the year. The developed model is considered a simplified statistical approach because it depends on two monthly constant predictors (S_0 & $\cos(\theta_{ZMT})$) and one daily changeable predictor ($\bar{T}$). The estimated high global solar radiation of the summer months is required for detailed study to get the maximum benefits of solar energy for electric power production and for estimating UVI_{max}. Consequently, the estimated H and T_{max} are used to construct accurate simplified estimation model of daily UVI_{max}. The results show that, the value of UVI_{max} increases with the increase in the value of maximum temperature, so that the increase be linked to the high values of H foreach day in that month. Additionally, the study recognized adverse effects of excessive solar radiation on the skin, the eyes and the immune system and outlines new approaches on how to improve the effectiveness of the UVI as a public awareness tool toward encouraging sun protection behavior. The study also clarifies the late and low level effects of ionizing radiation on health.

Although radiation biology cannot currently provide direct evidence of low dose effects in human health, a comprehensive understanding of radiobiological mechanism would facilitate epidemiological studies and improve the precision of a dose-response relationship at low dose levels. The integration of biological and epidemiological studies along with social science research will allow firmer conclusions about low dose effects on human health on the basis of social trust. Insights from health behavior theory and health communication science and recent developments in information technologies may offer opportunities to improve the effectiveness of UVI communication efforts. One important approach to increase the effectiveness of public health campaigns relies on strategic design of the intervention, including a specific definition of the target group and theory- and evidence-based development of the campaign message.

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