Chapter 1

Introduction

1.1 UV radiation (UVR)

The UV radiation is part of electromagnetic radiation. Its wavelength ranges from 100-400 nm. UV radiation (UVR) has been generally classified into three types or bands:

1. UVA (315-400 nm). Not absorbed by the ozone layer.
2. UVB (280-315 nm). Mostly absorbed by the ozone layer.
3. UVC (100-280 nm). Completely absorbed by the ozone layer and oxygen.

This classification is the most common and suggested by the International Commission on Illumination (CIE). However, the three regions are defined slightly different in some books that are produced by World Health Organization (WHO) (Moseley 1988).

1.2 Solar UV radiation

The spectrum of solar UVR at the earth's surface does not extend below 290 nm, due to the absorption by stratospheric ozone and by scattering and absorption processes in the troposphere (Webb 1997). The intensity of solar radiation decreases rapidly below 315 nm as shown in figure (1.1). The wavelengths below 315 nm contributes less than 1.5% to the total solar radiation reaching the earth's surface (Driscoll 1997). However, the component of UV radiation from the sun comprises about 95% UVA and 5% UVB (IARC 1992). UVA contributes about 20% of the harmful effects of UVR, wherease UVB is responsible for the remaining 80% (Diffey 1994).

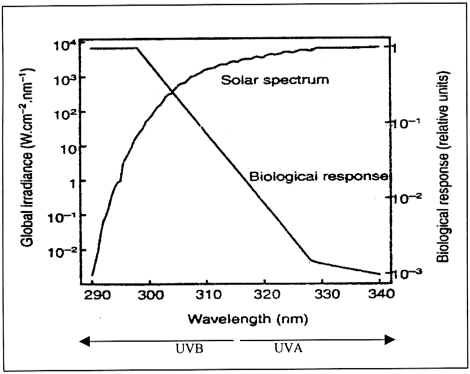

Figure (1.1): Spectrum of Solar UVR and the biological response (Weatherhead 1997)

It is in the UVB region that the most interest has been focused in the measurement of solar UVR and its impacts. The most effective wavelength of solar radiation that produces harmful health effects, such as erythma (sunburn), occur in the UVB region. For instance, wavelengths of 305 nm is a thousand times more effective than wavelengths of 350 nm in inducing biological response (Mckinley and Diffey 1987). However, UVA that has greater penetration into the skin, also contributes to the induction of cancer.

1.3 Solar radiation and zenith angle

The path length for the direct beam of solar radiation is governed by astronomical factors, that is the position of the earth relative to the sun. From a reference point at the earth's surface, path length is a function of solar zenith angle. It is the angle between the normal to the local plane of the surface (the vertical) and the position of the sun as show in figure (1.2).

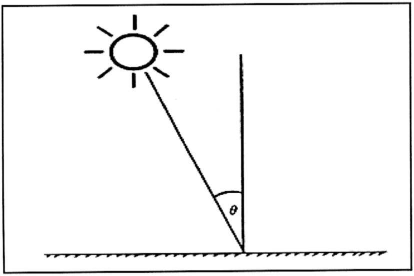

Figure (1.2): The zenith angle (θ), which the sun makes with the vertical

Zenith angle depends upon place (latitude), season and time of day. The shortest possible path length occurs when the sun is directly overhead. The longest path lengths occur close to sunrise and sunset, and at high latitudes the zenith angles are large (long path lengths) all the year round as the sun never appears very high in the sky. Thus for a given location the zenith angle is constantly changing on two time scales, daily and annualy.

1.4 Level of solar UV radiation

Solar UVR levels reaches the earth's surface varies depending on many factors, as shown in table (1.1). These factors, ozone concentration, time of day and year, latitude, altitude, weather condition and ground reflection are discussed below:

Factor		UV level	Factor		UV level
Ozone concentration	High	Low	Latitude	High	Low
	Low	High		Low	High
Time of day	Morning	Low	Altitude	High	High
	Noon	High		Low	Low
	Evening	Low	Thick cloud		Low
Time of year (summer)		High	High reflection surface		High

Table (1.1): Factors that affect UV level reaching the earth surface

1.4.1 Stratospheric ozone

The ozone layer absorbs most of the sun's UVR. The amount of absorption has decreased in recent years as the ozone layer has thinned out due to the release of chloroflourocarbon's components.

Ozone and its depletion will be discussed in section (1.6).

1.4.2 Time of day

At noontime, the sun's ray has the least distance to travel through the atmosphere and reach the earth's surface. Hence, UV level is high around this time. In the early morning and late afternoon, the sun's rays pass through the atmosphere at an angle and their intensity is greatly reduced.

1.4.3 Time of year

The sun's location varies with the seasons, causing the intensity of UV radiation to change with the time of year. UV level tends to be highest during the summer months, where the sun is directly overhead at noon in these months.

1.4.4 Latitude

The sun's rays are strongest at the equator, where the sun is most of the time directly overhead and UVR travels the least distance through the atmosphere. Ozone is also naturally thinner in the tropics compared to the middle and high latitudes (figure 1.3) causing less UVR being absorbed. At higher latitudes the sun is lower in the sky, so UVR travels a greater distance through the atmosphere and causes less intensity at that location.

1.4.5 Altitude

UV levels increases with altitude because there is fewer layers of atmospheres. Thus, at higher altitudes, the risk of overexposure increases.

1.4.6 Weather Conditions

Clouds reduce UV levels, but not completely. Depending on the thickness of the cloud cover, it is possible to burn and increase the risk of skin and eye damage on a cloudy summer day, even if it does not feel very warm. The attenuation of UVR by clouds will be discussed in section (1.5.3).

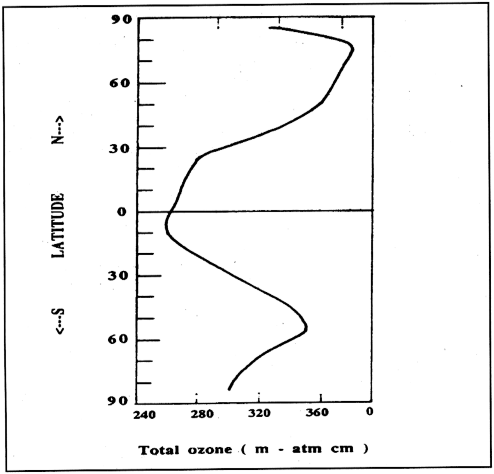

Figure (1.3): Latitudinal variation of total ozone (Ilyas 1991)

1.4.7 Reflection

Radiation reflected by the earth may return to space, or may undergo further reflection thus enhancing the incident radiation. Some surfaces, such as snow, sand, grass, or water can reflect much of the UVR that reaches them. Snow has very high reflectivity for the UVR. Fresh clean snow can reflect up to 100% of UVR (Webb 1997). The following table (1.2) show the UV reflectivity for some surfaces.

Wavelength (nm)	Grass	Concrete	Sand	Snow
UVA	0.019	0.131	0.203	0.656
UVB	0.017	0.098	0.152	0.630

Table (1.2): UV reflectivity for some surfaces (Feister 1995)

1.5 Attenuation of solar UV radiation

Solar UV radiation can be reflected and scattered as well as absorbed. Gaseous molecules and other particles cause the scattering, which is called Rayleigh and Mie scattering. While, aerosols, ozone and clouds droplets cause the absorption.

1.5.1 Rayleigh scattering

Attenuation of solar radiation by gaseous molecules, particularly oxygen and nitrogen, is referred as Rayleigh scattering.

Rayleigh scattering (scattering due to Brownian motion of gaseous molecules) occurs in the cleanest of atmospheres and is a function of wavelength λ^{-4}.

Thus UV radiation is strongly scattered, and in general more than half of the total UV radiation reaching the ground will be scattered (Webb 1997). It is of greater significance than ozone for attenuation of UV with wavelengths longer than 310 nm as shown in figure (1.4) (Moseley 1988),.

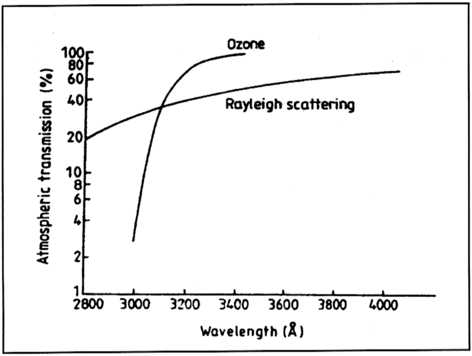

Figure (1.4): Comparison of attenuation of solar radiation by ozone and Rayleigh scattering (Koller 1969)

1.5.2 Mie scattering

Mie scattering occurs on larger particles with radii between 0.1 and 25 times greater than the wavelength of the incident radiation (Webb 1997). As particle size increases the forward scattering of Mie processes increases.

Mie scattering occurs on aerosol and cloud droplets, and is dependent on the size of the particles and their concentration.

1.5.3 Cloud reflection and absorption

Reflection of radiation back towards space can occur from clouds or at the surface of the earth. Clouds can reflect, scatter and absorb UV radiation. Radiation reflected from cloud tops will not reach the ground. The degree to which each process occurs depends upon the cloud type, thickness and distribution, and on the wavelength of UV radiation. Clouds can reduce UV radiation reaching the ground by as much as 90% on a given day (Frederick 1990). A thick, dark layer of cloud severely reduces the incident radiation and prevents any direct beam radiation reaching the ground.

A correction factor (F) is commonly applied to irradiant calculation (Green et al 1974). F is given by the following equation:

$$F = 1-0.056C \quad \ldots\ldots\ldots \quad (1.1)$$

where C is the cloud index in tenths of sky covered from 0 to 10, and 10 being complete sky covered.

1.5.4 Aerosols attenuation

Aerosols in the atmosphere also absorb or scatter radiation. It comprises of small-suspended particles in air and is mostly to be found within one or two kilometers of the earth's surface. An atmosphere that containing aerosol is considered hazy.

Aerosols and pollutants can reduce UVR by up to 40% (Liu et al 1990). In fact, attenuation coefficient (per unit thickness) of atmosphere is greater for aerosol scattering than for Rayleigh scattering (Moseley 1988). The sources of aerosol can be natural or man-made.

1.6 Ozone

Ozone, a molecule of three oxygen atoms O_3, occurs throughout the lowest portion of the earth's atmosphere, between 15 and 50 km above sea level (the troposphere and stratosphere). Ozone can absorb UVR of wavelengths less than 340 nm (Webb 1997).

The ozone layer shields the earth from harmful UV radiation. Ozone depletion, as well as seasonal and weather variations, causes different amounts of UV radiation to reach the Earth at any given times.

1.6.1 Ozone depletion

The amount of ozone in the stratosphere is controlled by a photochemical balance between production and destruction. The basic reactions are:

$$O_2 + h\nu \longrightarrow O + O$$

then $$O_2 + O + M \longrightarrow O_3 + M \quad \text{(Production)}$$

and $$O_3 + h\nu \longrightarrow O_2 + O$$

then $$O_2 + O \longrightarrow 2O_2 \quad \text{(Destruction)}$$

where $h\nu$ is the required energy from solar radiation of wavelength $\lambda < 242$ nm for production and $\lambda < 1200$ nm for destruction (Webb 1997), and M symbolizes any third molecule that must be involved in this collision.

Ozone and oxygen in the atmosphere can totally absorb UVC. Even with severe ozone reduction UVC can still be absorbed by the remaining oxygen particles. UVB is affected by changes in ozone column. For instance, a 1% decrease in the ozone column at 60° N latitude in the winter time was estimated to cause an increase of nearly 1% in the UVB intensity (De Fabo et al 1990).

Stratospheric ozone concentration have been decreasing since at least 1979. Over middle altitudes in both hemispheres, there has been a downward trend of about 3% per decade in the average amount of ozone since 1979 (Driscoll 1996). In Antractica a large increase in surface UVB radiation has been detected during spring time. The total ozone column is not uniform, figure (1.3), but varies with latitude and time of the year. At the same latitude, away from the equator and tropics, the total ozone column tends to be greater in spring than in autumn, this means more UVB in early autumn than in early spring. In the tropics, the relatively constant ozone column and similar solar angles throughout the year result in little variation in solar UVB with season, without cloud cover and atmospheric pollution being taken into account.

1.6.2 Ozone and chlorofluorocarbon (CFCs) compounds

The chlorofluorocarbon (CFCs) family of gases did not exist in nature, but was created by man. They are non-reactive substances at ground level, but in the stratosphere they are exposed to shorter wavelength of solar radiation and the molecules are dissociated, releasing atoms and molecules which are very efficient catalytic destroyers of ozone as shown in the following equation:

$$X + O_3 \longrightarrow OX + O_2$$

then $OX + O \longrightarrow X + O_2$ (Destruction)

where, X is Cl, Br, NO, OH or H, for example.

For instance, Freon (chlorofluoromethanes) components is used as propellant gases in refrigerants and spray cans, such as, paints, perfumes, hair sprays, insecticides, etc. In the stratosphere, these components affect the decomposition of ozone, as shown in figure (1.5)

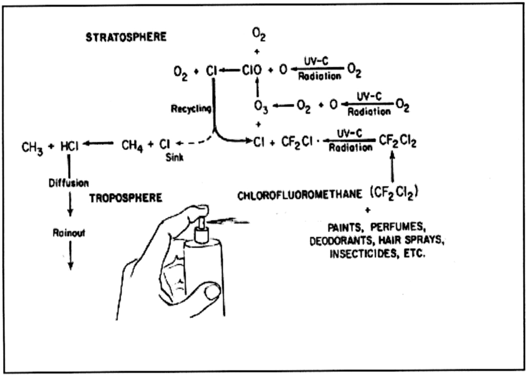

Figure (1.5): Effect of Freons on the decomposition of ozone in the stratosphere (Arthur 1976)

1.7 Health effects from UV radiation

Energy from the sun sustains all life on earth. However, some forms of sun energy can be harmful to life.

UVR can cause the following problems, particularly for people who spend substantial time outdoors. It includes skin cancer, cataracts, suppression of the immune system and premature aging of the skin as described in section 1.7.1 to 1.7.2.

UV-B is the most harmful to us and other life forms. It causes skin cancer and cataracts in human and also reduces the growth of plants, and may affect the health of wildlife and other animals.

1.7.1 Eye

The penetration and absorption values of UVR in ocular tissues as a function of wavelength is shown in figure (1.6). Wavelengths shorter than approximately 290 nm are partially or completely absorbed within the cornea and conjunctiva (John A. Parrish 1978). The excessive exposure to sunlight UVR can damage the human eye. It may kill the cells in the outermost lining of the eyeball, and when these cells die, they become opaque and the individual becomes snow-blind (Keratoconjunctivitis), or reddening of the eyeball. As the dead cells begin to shed, the eyelid is less well lubricated and all eyelid movements become exceedingly painful.

Cataracts occurs after excessive exposure of the eye to UVB radiation. When it occurs, cloudy or opaque areas appear in the lens of the eye.

The chronic effects on the eye consist of the development of cataracts and squamous cell cancer of the conjunctiva.

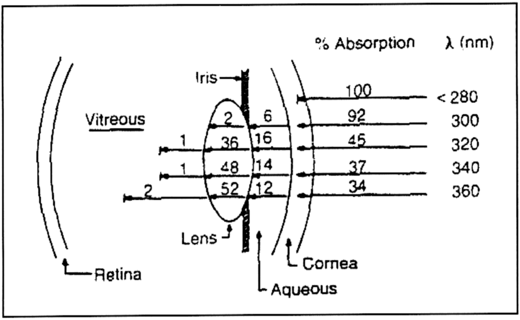

Figure (1.6): Penetration of UVR into ocular structure (Sliney 1980).

1.7.2 Skin

Acute effects of UV radiation on the skin consists of solar erythma, which is the reddening of the skin. The reddening begins after four to fourteen hours of exposure and reaches a peak in ten to twenty four hours. Erythma is caused by a composite of effects on the epidermis (the outer layer of the skin) mainly by the UVB radiation near 300 nm (Arthur 1976), and on the dermis (the inner layer of the skin) by UVA radiation, figure (1.7).

Chronic skin changes in humans consist of skin cancer. It is localized mainly on the head and neck, figure (1.8), and represents 91.2% of whole skin cancer. It occurs in the form of nodules on the skin or grows downward into the dermal connective tissue.

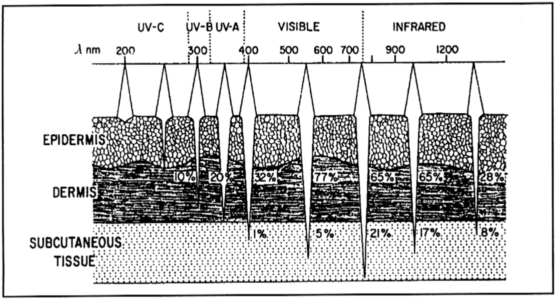

Figure (1.7): Differential transmission of UV in various layers of the skin (Arthur 1976)

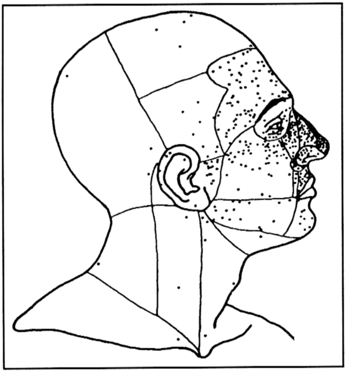

Figure (1.8): Localization of skin cancers on the human head (Arthur 1976)

The probability of getting skin cancer depends on several factors. Among these is the part of the body exposed to the sunlight, duration of exposure to sunlight, people at lower latitude and higher altitude, and skin whiteness.

1.8 Dosimetry method for solar UV radiation

The total solar radiation reaching the earth's surface consists of two components, direct and defuse. The UVR that is falling upon a horizontal surface from all directions is the quantity that is most frequently measured. The UVR component of terrestrial radiation from the sun comprises about 95% UVA and 5% UVB (IARC 1992).

1.8.1 UV detector

The characteristics of detectors used and its calibration are important in determining the accuracy of measurements. Three main types of measuring systems are used to obtain information relating to solar UVR levels. These include, spectroradiometeric monitoring equipment, broadband measurement equipment and personal UVR dosimeters.

1.8.1.1 Spectroradiometers

Spectroradiometers measure irradiance within a narrow bandwidth from 290 to 400 nm, centered at a wavelength. The data may then be weighted with a particular biological action spectrum to assess the health and/or environmental impacts.

The basic components are illustrated in figure (1.9).

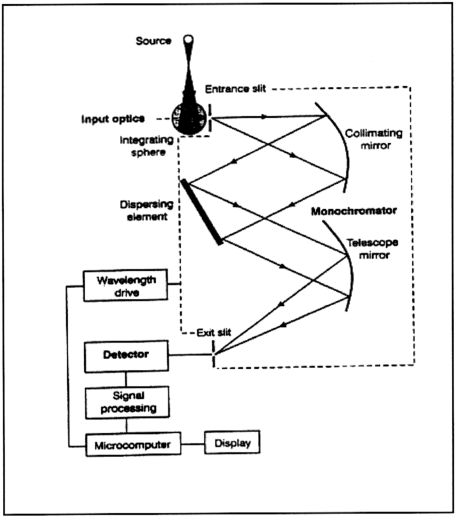

Figure (1.9): Basic components of a spectroradiometeric system (Driscoll 1997)

The major components are:

1. Input optics. Where the optical radiation is collected.
2. Monochromators. It collimates, select and reflect the entrance beam from an entrance slit.
3. Detector. Either photomultiplier tube or photodiode. It receives the emerging light from the exit slit of monochromator. The signal from detector is then integrated and transferred to a microcomputer for storage and display.

1.8.1.2 Broad band instruments

It provides measurements over selected wavelength ranges of biologically weighted irradiance. The measurement methods use two physical phenomena, either thermal or photoelectric.

1.8.1.2.1 Thermal detectors

The energy absorption is measured by detecting the change in temperature inside the detector. Thermal detectors have a uniform response within their region of operation and are particularly useful for the absolute determination of irradiance and as such are often used as calibration instruments.

1.8.1.2.2 Photoelectric detectors

It involves a conversion of UVR into an electric signal. This device includes photomultiplier tubes, vacuum photodiodes, silicon photodiodes and GaAsP photodiodes.

1.8.1.3 Personal dosimeters

Film dosimeters and CR-39 plastics have a response that approximates to the reference erythma action spectrum (Wong 1992).

Other personal UVR devices include personal sun alarm, UVR sensitive stick-on tape, sun sensors, timers and small monitors. Many of these are very poor indicators of UVR dose. Photoluminescence and thermoluminescence dosimeters and diazo film is also used to detect UVR (WHO 1979).

1.9 UV radiation safety

Overexposure to solar UVR is a considerable public health problem. It is important to modify the behavior of exposed workers to solar radiation. The development of exposure limits to solar radiation has involved the study of acute and chronic injury to both the eye and the skin.

1.9.1 UV index

The index is a measure of the solar UV levels relevant to the health effects and useful for warning people about the degree of hazard that existed or could exist on a particular day. It is determined (Bernhardt 1997) by the following equation:

$$UV\ index = CIE\text{-}weighted\ irradiance \times 40 \quad \ldots\ldots\ldots \quad (1.2)$$

Or

$$= Time\ weighted\ average\ effective\ irradiance\ (W.m^{-2}) \times 40$$

where CIE is the international commission on illumination.

The scale of this index is, 0 to 2 Minimal, 3 to 4 Low, 5 to 6 Moderate, 7 to 9 High and 10+ Very High as shown in table (1.3). The larger the number, the more intense the UVR. The UV Index is zero at nighttime, whereas the burn time would be at noontime.

It refers to the daily maximum effective irradiance at the earth's surface averaged over a period of between 10 and 30 minutes. It is defined as the maximum daily value and in most instances will occur when the sun is directly overhead. However it can occur at other times during periods of clearing or developing cloud. The UV index can be based on either measurements or predictions.

Scale level	Specification
0-2	Minimal
3-4	Low
5-6	Moderate
7-9	High
10+	Very high

Table (1.3): Scale of UV index

1.9.2 UV radiation exposure limits

The maximum permissible exposure (MPE) is determined at the wavelength 270 nm that is the most damaging wavelength. MPE values for other wavelengths can be calculated relative to radiation of wavelength 270 nm and is given by the effective irradiance E_{eff} (W m^{-2}) according to the equation;

$$E_{eff} = \Sigma E_{\lambda} S_{\lambda} \Delta\lambda \quad .... \quad (1.3)$$

where E_{λ} (W m^{-2} nm^{-1}) is the spectral irradiance at wavelength λ, S_{λ} is the relative spectral biological effectiveness as shown in table (1.4) and $\Delta\lambda$ (nm) is the interval employed in the measurement of E_{λ}.

The maximum permissible exposure t (s) may be calculkated from the formula;

$$T=30/E_{eff} \quad .... \quad (1.4)$$

Ultraviolet radiant exposure in the spectral region 180 to 400 nm incident upon the unprotected skin should not exceed 30 $J.m^{-2}$. For exposure of the unprotected eyes, the total (unweighted) ultraviolet radiant exposure in the spectral region of UVA (315 to 400 nm) should not exceed 10^4 J m^{-2} (Bernhardt 1997 and Moseley 1988).

Wavelength (nm)	MPE (J m^{-2})	S_λ	Wavelength (nm)	MPE (J m^{-2})	S_λ
200	1000	0.03	270	30	1.00
210	400	0.075	280	34	0.88
220	250	0.12	290	47	0.64
230	160	0.19	300	100	0.30
240	100	0.30	305	500	0.06
250	70	0.43	310	2000	0.015
260	46	0.65	315	10000	0.003

Table (1.4): Maximum permissible exposure (MPE) and relative spectral effectiveness (S_λ) at different wavelengths, Moseley (1988)

1.9.3 Protection against solar UV radiation

The following guidelines should be considered when it is expected the intensity of UVR is high at a certain area:

1. Cover the head with a hat
2. Wear the cloth that reflect most harmful part of the UVR
3. Reduce the activity outside the house and near the beach
4. Wear sun glasses with high sun protection factor (SPF) of 15 or more (Bernhardt 1997)

5. Wipe parts of the body exposed to sunlight with special cream
6. Get the value of UV index through the radio, television, etc.

1.10 UV radiation units.

UVR induced biological effects depends on the wavelengths of the radiation. It is necessary for a proper determination of hazard to have spectral emission data. These consist of:

1. Spectral irradiance (W m^{-2} nm^{-1}) measurement or calculations of emissions from the source.
2. The total irradiance (W m^{-2}) is obtained by summing over all wavelengths emitted.
3. The biological or hazard weighted irradiance (W m^{-2} effective) is determined by multiplying the spectral irradiance at each wavelength by a biological or hazard weighting factor and summing over all wavelengths.
4. The biological effective radiant exposure (J m^{-2} effective) can be calculated by summing the biologically weighted irradiance over the exposure period.

1.11 Objective of the project

Due to the high intensity of solar UVR at the equator (Ilyas 1991) and the possibility it may affect life in this region, it is important to detect and monitor solar UVR to check the variations in its intensity and to determine its harmful degree. The main objective of this study is to detect solar UVR by using thermoluminescence (TL) material. The advantage of TL materials as a dose meter is that no electronic circuits associated during the exposure.

This material is mainly used to detect ionizing radiation. In the current study, we will discuss the possibility to use them in the detection of non-ionizing radiation that is solar UV radiation using intrinsic technique. Some of them have been previously approved to be used in UV dosimetry as shown in table (1.5).

Year	Author(s)	phosphor	Remarks
1951	K. Watanabe	$CaSO_4$:Mn	Sensitive to wavelength < 134 nm. Was used to measure UV and x-ray at high altitude.
1972	Edwin et al.	CaF_2	Can measure wavelength > 290 nm. Its sensitivity covers most erythemally effect energy.
1975	Bassi et al.	CaF_2:Dy	Treated TLD-200 at high temperature has high sensitive to UV.
1976	Bassi et al.	CaF_2:Dy	TLD-200 can cover erythmal dose of skin (12.6 mJ/cm^2).
1976	Buckmann & Payne	LiF	TLD-100 is sensitive to low level of UV light (0.1 uW/cm^2) and has linear response from low exposure up to 6000 uJ/cm^2.
1983	Pradhan & Bhatt	CaF_2:Dy CaF_2:Mn	An increase intrinsic UV sensitivity after temperature treatment is property to all CaF_2-based TLD. Sensitive to wavelength of UV < 260 nm.
1991	Aguirre et al.	NaCl:Eu	Sensitive at actinometric region of solar radiation.
1994	Oster et al.	AL_2O_3:C	Highly sensitive to low UV when pre-irradiated.
1996	Potiens & Campos	$CaSO_4$:Dy	Mix with Teflon and show good PTTL for UV dosimetry.
1996	Delgado et al.	LiF	Possibility to measure low dose of UV radiation by PTTL technique.
1996	Pradhan et al.	AL_2O_3:C	Most sensitive TL materials to UV and ionizing radiation and visible light does not cause intrinsic TL.
1996	Yeh & Su	Gd_2O_3:Eu Y_2O_3:Eu	Expose to sunlight using filter. Linear at different regions.
1996	Melendrez & Perez	KCl:Eu	Suitable in actinic region of UV and all type of radiation.
1996	Melendrez & Perez	KBr:Eu	Good for UV, Gamma and X-ray.
1996	Fukuda et al.	CaF_2:Tb	Expose to sunlight without filter. Suitable for UVB and UVC when increasing sintering temperature.
1997	Bhatt et al.	$BaSO_4$:Eu $CaSO_4$:Dy	First one is more sensitive and its intrinsic UV response is the highest among TL phosphors.

Table (1.5): Overview of TL materials in UV dosimetry