INTRODUCTION

Ultraviolet (UV) radiation can cause health damage in many ways --

- to the skin: burning, premature aging, and possible skin cancer
- to the eyes: possible cataracts and other disorders
- to the body's immune system.

This Note discusses the interpretation of the Health EnviroMonitor® system's UV readings in terms of possible skin damage. One should, however, be aware of the other hazards and minimize exposure to UV.

The UV SPECTRUM

UV radiation is divided into three spectral regions: UV-A, wavelengths of 400 to 320 nanometers (nm); UV-B, 320 to 280 nm; and UV-C, 280 to 100 nm.

The earth's atmosphere absorbs wavelengths shorter than 290 nm (UV-C). UV-B rays pose the greatest risk of skin cancer. Some UV-A radiation is needed by the human body for the synthesis of vitamin D, but excessive amounts cause aging, wrinkling, and loss of elasticity of the skin, and they contribute to skin cancer and cataracts.

The Erythemal Action Spectrum (EAS) was defined by McKinlay and Diffey (1987) and has been accepted by the Commission Internationale de l'Eclairage (CIE) as the standard representation of the average skin response to UV-B and UV-A. As shown by the EAS (heavy straight lines) plot in Figure 1, the skin is 100 times more sensitive to radiation at 298 nm than to that at 319 nm. The plot with round data points shows the spectral response of a Davis model 7841/7843 UV Sensor. The other curve gives the response of a Yankee Environmental Systems model UVB-1 Ultraviolet Pyranometer.

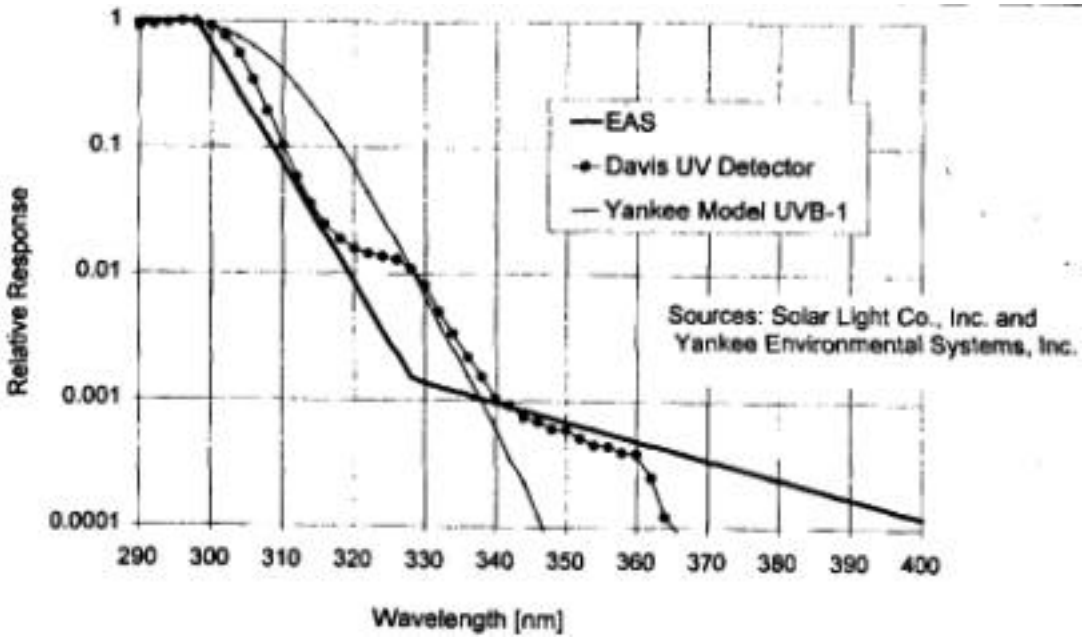

Figure 1. Erythemal Action Spectrum and the UV Sensors' Spectral Responses.

UV MEASUREMENTS

The Health EnviroMonitor system displays two types of UV measurement: **Intensity**, the strength of UV radiation at the moment of measurement, and **Dose**, the total UV energy measured over a period of time.

INTENSITY

The UV intensity at a given instant is usually defined in one of three ways:· The scientific measure of UV irradiance is usually given in units of Watts per square meter.· The UV Index has been defined to give a more-easily-remembered set of units, ranging from 1 to 15.

· The intensity may also be defined as a Dose-rate, MEDs per hour.

The Health EnviroMonitor calculates and displays the Index and Dose-rate.

It should be noted that when the UV sensor is not aligned with the direct solar irradiance, measurements may understate the UV intensity at surfaces normal to the sun's rays. In other words, if the sensor is aligned with the sun at solar noon, at times other than solar noon the readings may be less than the actual intensity on the portions of an individual's body that are normal to the sun's rays.

UV Index. The Index was first defined by Environment Canada and has since been adopted by the World Meteorological Organization. In the U.S. the Environmental Protection Agency (EPA) has categorized the Index values as follows:0 to 2, Minimal

3 to 4, Low
5 to 6, Moderate
7 to 9, High
10 and higher, Very High.

The Index is equal to the EAS-weighted irradiance (in Watts/m_) x 40. An Index of 10 is equivalent to an EAS-weighted irradiance of 0.25 W/m_. The relationship between Index value and estimated time for sunburn is discussed below.

The Index value published by the U.S. National Weather Service is a forecast of the next day's noontime UV intensity (see Long, et al). The Index value displayed by the Health EnviroMonitor is the result of a real-time measurement.

Dose-rate. The Dose-rate is expressed in MEDs per hour, where a MED is the Minimum Erythemal Dose, the amount of sun exposure which causes barely perceptible skin sunburn redness (erythema). The MED and its scale factor are discussed below under DOSE.

For a MED scale factor of 1.0 (the base, or default, value) a Dose-rate of 4.3 MEDs per hour is equivalent to an Index of 10. Stated another way, the base MED rate is 3/7 of the Index value.

DOSE

As mentioned above, the MED, or Minimum Erythemal Dose, is the integral, or summation, of UV intensity over a period of time; it is the amount of EAS-weighted energy which causes barely perceptible redness to appear within 24 hours in previously-unexposed skin. The Health EnviroMonitor calculates the dose by performing a real-time integration of EAS-weighted intensity.

The base MED is equal to 21 mJ/cm_ of EAS-weighted UV energy.

It's obvious that not all skin types have the same sensitivity to sunlight. The following sections discuss the interpretation of dose information for various skin types.

SKIN TYPES

The EPA has defined four skin phototypes to help individuals interpret UV data for their own sensitivities; these definitions are shown in Table 1a. Within each skin type a range of sensitivities will be found; some

Table 1a. Description of Four Skin Phototypes (Source: EPA -017)

SKIN PHOTOTYPE	SKIN COLOR IN UNEXPOSED AREA	TANNING HISTORY

1	Never Tans, Always Burns	Pale or milky white; alabaster	Develops red sunburn; painful swelling; skin peels.
2	Sometimes Tans, Usually Burns	Very light brown; sometimes freckles	Usually burns; pinkish or red coloring appears; can gradually develop light brown tan.
3	Usually Tans, Sometimes Burns	Light tan, brown, or olive; distinctly pigmented	Rarely burns; shows moderately rapid tanning response.
4	Always Tans, Rarely Burns	Brown, dark brown, or black	Rarely burns; shows very rapid tanning response.

Table 1b. Description of Six Skin Types (Source: Environment Canada)

SKIN TYPE	CHARACTERISTICS	TANNING HISTORY
I	Blond hair, blue or green eyes, very light skin.	Always burns easily, never tans
II	Light to medium hair, eyes, and skin.	Always burns easily, tans minimally.
III	Medium hair, dark eyes, medium skin.	Burns moderately, tans gradually.
IV	Dark hair and eyes, light brown skin.	Burns minimally, always tans well.
V	Dark hair and eyes, very dark skin.	Rarely burns, tans profusely.
VI	Dark hair and eyes, very dark skin.	Never burns, deeply pigmented.

people will experience sunburn more quickly than others of the same phototype. Environment Canada has defined six skin types, as defined in Table 1b.

DOSE TO BURN

Figure 2 attempts to show the UV dose that will cause sun-burning of various skin types. The four EPA skin phototype ranges are shown on the left vertical axis; the six Environment Canada types are on the right axis. The data points and curve at the left edge of the shaded region are values suggested by Environment Canada as the doses at which the most sensitive people of each skin type will begin to burn. The horizontal bars are the ranges suggested by the EPA as the ranges of sensitivity for each of their four skin phototypes. UV Dose is shown in two sets of units: base MEDs and milliJoules per square centimeter.

In summary: at the UV dose represented by the left edge of the shaded region some individuals of that skin phototype will experience sunburn; at the right-edge dosage everyone of that type will be burned. The "Minutes to Burn" calculation of the Health EnviroMonitor Link software gives the time to reach minimum sunburn based on the six Environment Canada dose values.

It must be remembered that reflected UV can play a large role in sun-burning, and the UV sensor may not be in a position to measure all the reflected radiation to which an individual -- one sitting sitting beside a swimming pool, for example -- might be exposed. That person, then, could be receiving a larger dose than the weather station's measurement would indicate.

MED Scale Factor. The Health EnviroMonitor includes provisions for applying a scale factor to the MEDs readings, enabling the MED value to be adjusted for each skin phototype. This adjustment can be made such that 1 MED will be the approximate minimal-burn dose for the desired skin phototype. Table 2a lists suggested ranges of scale factors for each of the four EPA skin phototypes. Table 2b lists suggested ranges for the Environment Canada skin types.

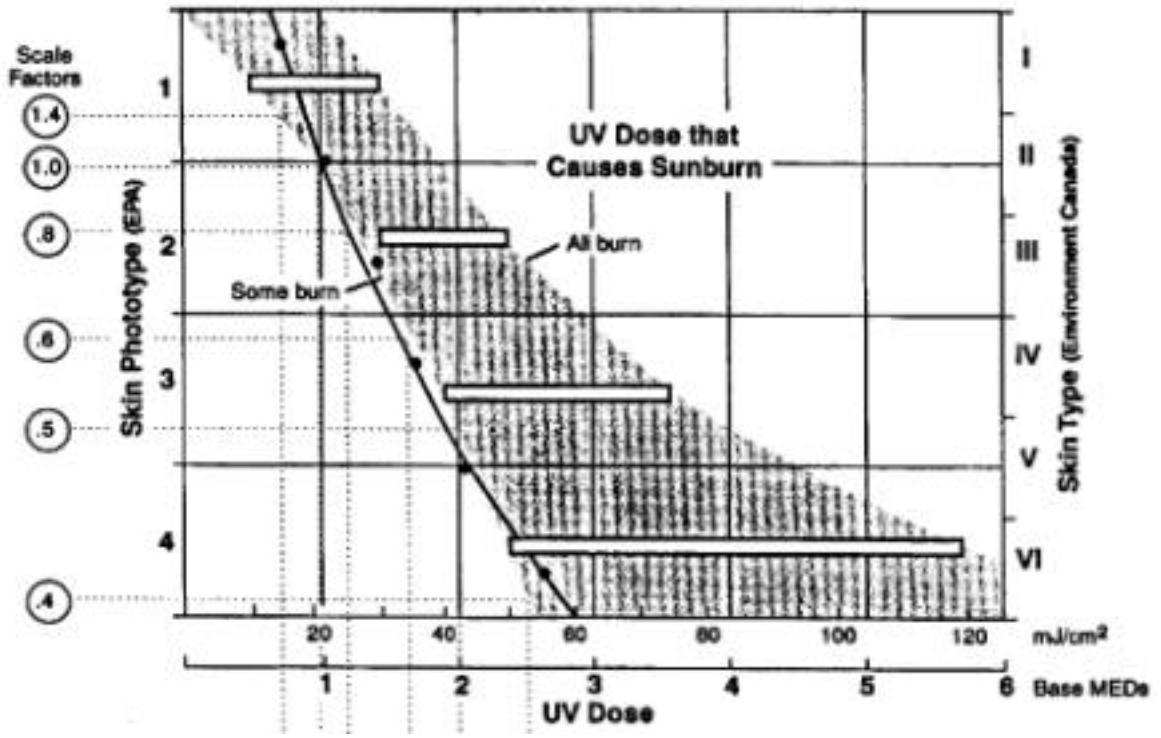

Figure 2. UV Dose That Causes Sunburn (Sources: EPA and Environment Canada)

The scale at the bottom of Figure 2 shows graphically how the MED scale will be altered by the application of the scale factor: when the scale factor is 1.0, a measured dose of 21 mJ/cm^2 will cause the display to read 1 MED; when the scale factor is set at 0.5, it takes a measurement of 42 mJ/cm^2 to cause the display to read 1 MED. The circled numbers at the left of the figure show where a scaled value of one MED intersects the left edge of the shaded area.

Table 2a. Suggested MED Scale Factor Ranges (four skin types)

SKIN PHOTOTYPE (EPA)		SCALE FACTORS
1	Never Tans, Always Burns	1.0 to 1.4
2	Sometimes Tans, Usually Burns	0.7 to 1.0
3	Usually Tans, Sometimes Burns	0.5 to 0.7
4	Always Tans, Rarely Burns	0.3 to 0.5

Table 1b. Description of Six Skin Types (Source: Environment Canada)

SKIN TYPE (Environment Canada)		SCALE FACTOR
I	Always burns easily, never tans	1.4
II	Always burns easily, tans minimally	1.0
III	Burns moderately, tans gradually	0.7
IV	Burns minimally, always tans well	0.6
V	Rarely burns, tans profusely.	0.5
VI	Never burns, deeply pigmented.	0.4

An individual has two alternative ways to use the data of Figure 2 and the Health EnviroMonitor system's UV measurements to monitor and anticipate the UV dose that will cause sunburn:

a. Leave the Scale Factor at 1. One can look at Figure 2 and decide on the base MED dose that seems appropriate. A person with Type 1 skin might choose 0.5 MED as the maximum for the day; a person with Type 4 skin might consider 3 MEDs a reasonable dose for the day. This method will probably be the more suitable one when people of different skin types wish to use the data. It also has the benefit of providing better resolution and a wider range for the setting of dose limits.

b. Set a Scale Factor. From either Figure 2 or Table 2 one can choose a scale factor such that a dose of approximately one MED is the appropriate dose. After this is entered, all MEDs dose readings and MEDs/hour dose-rate readings will be scaled accordingly.

TIME TO BURN

To estimate the length of exposure time that will cause sunburn one can divide the Dose to Burn by the current Dose Rate. For example: 0.8 MEDs ÷ 3.2 MEDs/hour = 0.25 hour = 15 minutes. This method is correct for all settings of the MED scale factor.

The above Time to Burn equation must be used with caution. The Dose Rate can be expected to change during the dose period, so the Time to Burn will change. If, for example, the dose period is begun before solar noon the Dose Rate will probably increase during the period, so the Time to Burn will be shortened.

Similarly, if the initial Dose Rate is observed during a period of cloudiness or overcast, the subsequent Dose Rates and Time to Burn will be quite different if the sky clears.

REFERENCES

Environmental Protection Agency, 1994: Experimental UV Index. EPA 430-F-94-017, -018, and –019.

Long, C. S., et al: Ultraviolet Index Forecasts Issued by the National Weather Service. *Bulletin of the American Meteorological Society, April 1996.*

McKinlay, A. F., and B. L. Diffey, 1987: A reference spectrum for ultraviolet-induced erythema in human skin. *Human Exposure to Ultraviolet Radiation: Risks and Regulations.* W. F. Passchier and B. F. Bosnajakovic, eds., Elsevier, 83-87.

Davis Instruments
3465 Diablo Avenue, Hayward, CA 94545 U.S.A.
Phone: 510-732-9229 • Fax: 510-732-9188
sales @davisnet.com • http://www.davisnet.com