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SOLAR UV-B ATMOSPHERIC AEROSOL STUDIES AT ANTARCTICA

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Abstract

Solar radiation intensities in the wavelength range of UV-B, visible and near Infra red (280-800 nm) were monitored over Indian Antarctic Station Maitri during the 17th Indian Antarctic Scientific Expedition. From the solar radiation intensity measurements in LIV-ES range the erythemal Doses in the units of predefined Minimum Erythemal Doses per hour (MED/Hr) are derived and their characteristics are studied during this period. It is found that maximum MED values reached during the month of December 1998 with its magnitude 4.00MED/Hr at local noon of 1st December 1998. The solar radiation intensities in the VIS-NIR range are used to derive and study the aerosol optical depths over Antarctica. From these studies it is found that the representative optical depths at 368, 500, 675 and 778 nm wavelengths, the corresponding optical depths are 0.75, 0.25, 0.097 and 0.048 respectively, which shows that at Antarctica the optical depth increases with decreasing wavelength. It is also seen from these studies that the aerosol optical depth has increased in comparison to the corresponding values during the previous years.

Introduction

The present human concern about the environment is inciting the scientific community to probe and characterise the different aspects of environment. The multifaceted involvement of the solar radiation in affecting the environment makes the solar radiation as an important environmental parameter. The solar radiation passes through the earth's atmosphere before reaching the earth surface. Any observation of solar radiation at earth surface will be having the signatures of the processes involved between the solar radiation and earth atmosphere. The Ultra-Violet solar radiations, which are sensitive to their interactions with the ozone gas present in the stratosphere, carry to the ground the signatures of the variabilities in the concentrations of ozone gas in the stratosphere. After the discovery of the ozone hole over Antarctica, the study of these ultraviolet radiations over Antarctica was recommended very strongly. In view of these recommendations National Physical Laboratory started an observational programme on UV-B radiations over Antarctica. The initial phase of these observations was carried out with a NPL built UV filter photometer (Srivastava and Sharma, 1979, Hanjura et al., 1988, Singh et al., 1992), but later on a new equipment called UV-Biometer was added to these observations. This equipment is designed to measure the UV-B intensities directly applicable to Erythema action studies. The NPL programme on aerosol optical depth studies is continuing with the sun-photometer. In the present communication the results on Erythemal dose, UV-B intensities and aerosol optical depths are presented.

Experimental Set up and Data Recording

UV-Biometer

The UV-Biometer measures ultraviolet radiation (both direct and diffuse) in the wavelength range of 280-340 ran using a wide band interference filter. This instrument uses fluorescent phosphor to convert UV-B radiation into visible light and then detect it using a solid state (Ga As) detector. The dc output from the detector is amplified and recorded. The detector's spectral response is designed to closely approximate the erythemal action spectra maximising approximately at the same wavelength. The final output from the

Biometer is proportional to the convolution of the solar UV spectrum H measured at ground, with the response function R, of the instrument such that

$$S(\chi) = \int H(\chi,\lambda) . R(\lambda) \, d\lambda \quad \text{———— (1)}$$

and the actual Erythemal dose rate D, is the convolution of H with the Erythemal action spectrum E,
given by

$$D(\chi, \lambda) = \int H(\chi, \lambda) . E(\lambda) \, d\lambda \quad \text{———— (2)}$$

Combining (1) and (2)

$$D(\chi) = F . S(\chi) \quad \text{———— (3)}$$

Where F is a function of atmospheric column ozone, total aerosol loading, cloud cover and solar zenith angle χ•

λ is the wavelength of the incoming radiation.

A computer programme is installed in the data logger which computes the function F and D for given conditions and matches the shape functions of D and S. The final output of the Biometer is converted and recorded in the units of Minimum Erythemal Dose per Hour (MED/Hr). The unit MED/Hr is defined as the UV-B energy of 5.83 microwatts/cm2 received continuously for one hour. The definition is derived after estimating that this amount of energy, falling continuously for one hour, starts reddening the skin of the of the general population in areas of colder regions for which this definition is devised. The biometer was operated at Indian Antarctic Station Maitri throughout the year 1998 for the days when the sun was visible. The period includes all the days with clouds and without clouds. The ozone values for this period is taken from the total ozone mapping spectrometer (TOMS) observations.

UV-Filter photometer

The UV-Filter photometer is an instrument which measures solar UV intensities at 280, 290, 300 and 310 nm wavelengths. The interference filters have 10 nm Full Width at Half Maximum (FWHM) and 15% transmission. The radiation after passing through the filters is detected by photo multiplier tube and the dc signal thus generated is in relative units and recorded into the data logger. The filter selection is performed by a filter wheel rotated by a synchronous motor. The filters change their position sequentially within 15 seconds one after other and stay for 45 seconds in front of radiation path. This instrument was also operated throughout the year 1998.

Sun Photometer

The sun photometer measures the solar intensity at four wavelengths i.e., 368, 500, 675 and 778 nm. The wavelength selection is performed by the interference filters having FWHM of 10 nm and transmission of about 15%. The filter selected radiation is detected by a solid state detector. The filters are rotated by hand to change the wavelength. The final output of this instrument is in absolute units. The atmospheric aerosol optical depths are derived from these measured radiations reaching the earth surface.

Result And Discussions

The data recorded by UV-Biometer throughout the year in the form of MED/Hr or MED/30 minutes is analysed on daily, monthly and yearly basis. One representative daily variation is shown in figure 1. Along with the Antarctic MED values the daily variation of corresponding values at various inland locations over Indian mainland are also shown in this figure. It is observed from this figure that MED maximises at the local noon at all the locations. This is a very logical straight forward conclusion. The highest values of MED are observed at Hanle (32°43'N; 77°34'E, 4467 meter Altitude), Second highest at Leh (34°77'N; 77°36'E, 3311 meter Altitude), Third highest at Antarctica (70°45'S; 11°45'E, 110 meter Altitude). The Delhi values are lower than those of Hanle, Leh and Antarctica. The daily maximum MED values for Hanle, Leh, Antarctica and Delhi are 5.0, 4.0, 3.8 and 2.3 respectively. It is evident from this figure that MED values remain above the threshold value (1.00 MED/Hr)for maximum time over

Antarctica. For Antarctica during summer this period is between 06.30 Hrs to 16.30 Mrs (Ten Hours), for Hanle and Leh both in summer between 08. 00 to 17.00 Hrs (Nine Hours) and for Delhi in summer months between 08.00 to 16.00 Hrs (Eight Hours). When Delhi and Antarctic values are compared it is seen that the local summer period values at Antarctic are not only more at maximum values of local noon but also their duration of being more than the threshold values is more at Antarctica than at Delhi. The rate of change of MED values are more at Hanle and Leh while they are similar at Antarctica and Delhi. This is quite interesting because ,rate of change of solar zenith angle at Antarctica and at Delhi are quite different. This similarity of MED change rate at Delhi and Antarctica seems to be due to the fact that at Delhi the environment is quite polluted and the MED does not change as fast as the change of solar zenith angle. So the slow rate of change of solar zenith angle is compensated by the presence of polluted environment at Delhi and thereby the MED rate of change comes quite close for Delhi and Antarctica.

The day to day variation of total column ozone in Dobson units and the local noon values of MED / 30 minutes for the month of October, November and December 1998 are shown in figure 2, 3 and 4 respectively. These values of ozone as well as MED values pertain to the real weather conditions including all sorts of weather variabilities. From figure 2 it is seen that the maximum MED values were 1.20/30 minutes or 2.40/Hour even though the ozone values were as low as 135 D. U. This is because of the fact that the solar zenith angle in the month of October is quite high and the path length for the solar radiation to travel is quite high and therefore the MED values do not go as high as they could have gone on the mainland with smaller solar zenith angle. The anti correlation between the column ozone content and the MED doses are observed during the whole month of October. The day to day variation of local noon MED for the month of November, 1998 shown in figure 3 shows that these values are quite high compared to the values for the month of October. This is due to the fact that the solar zenith angle decreases in the month of November compared to the month of the October. Figure 4 shows the clay to day variation of column ozone and local noon MED values for the month of December 1998. It is seen from this figure that MED values go op to 2.02 MED /30 minutes or 4.04 MED / Hour MED. When the column ozone values was 175.0 D. U. The high MED values in the month of December is due to the fact that solar zenith angle became substantially low during this month and whenever the ozone value dips a little bit from the normal values the MED values goes up. The normal value of ozone content is around 250 D. U. and whenever this comes down below 200 D. U. the MED values in the month of December go quite high for cloud free weather conditions. For ozone values above 250 D. U. and cloudy weather conditions the MED values may go very low as 0.45 MED/30 minute when the weather was cloudy and the column ozone content was 250 D. U.

The monthly average of the local noon MED values and total ozone content values have been calculated for all the months of the year 1998 and the month to month variation of these averages is analysed. This analysis is shown in figure 5. The MED observations are possible only during the time when the sun is visible. This is the reason why the average MED values for the months of May, June and July are not available and not shown in this figure. It is interesting to note from this figure that average ozone values as well as average MED values decrease from January to April and both of them increases from August to December. But in addition to this trend an extra feature of these trends is also seen from this analysis that the monthly rate of change of MED is faster than that of total ozone. This is true for both the pre Antarctic winter period and post Antarctic winter period of the year of 1998. Again this result is explainable on the basis of important role played by the fast changing solar zenith angle during the pre Antarctic winter period and post Antarctic winter period. This feature of Antarctic UV radiation environment is quite interesting in view of the ozone hole phenomena, the ozone contents goes quite low in the month of September and October but the solar zenith angle is quite high during these months. So the UV intensities do not go so high as they could have gone in the geographical regions with low solar zenith angles and low column ozone values. The average local noon MED values during the month of September and October remain below the threshold values.

The solar UV-B radiation intensities observed by the filter photometer at four wavelengths are analysed in a similar way as done for MED values obtained from Biometer. The daily, monthly and yearly variation of UV intensities for 280, 290, 300 and 310 nm wavelengths is studied for the whole year of 1998. The monthly average of local noon values of these intensities is calculated. As representative of these averages the figure 6 shows the month to month variation of UV radiation intensity at 310 run wavelength for the full year of 1998. Along with radiation intensities the month to month variation of monthly average of total column ozone is shown. The trend of monthly average UV intensities at 310 nm is quite similar to that of monthly average MED values shown in figure 5 and explanation of these trends is also similar to that given above.

The solar radiation intensities measured by Sun photometer at 368, 500, 675 and 778 nm wavelengths are used to derive the atmospheric aerosol optical depths at these wavelengths. These intensities were measured at different times of the day for clear weather conditions. The standard Langley technique is adopted to derive optical depths. In this technique a linear least square fit to the Lambert Bear Law, connecting the ground reaching solar flux to the extra terrestrial solar flux at any wavelength, is obtained between the sec chi, where chi is the solar zenith angle, on X axis and log I, where I is the radiation intensity measured at ground, on Y axis. From these linear least square fit mathematical operations the slope of linear fit gives the aerosol optical depth. The representative curves of this analysis are shown in figures 7, 8, 9 and 10 for the radiation wavelength of 368, 500, 675 and 778 nm for 20th Movember, 1998, which was a clear day over Maitri. On the top of these figures are written the equation of corresponding linear least square fits. The coefficients of X in the first term on right hand side of the equation gives the aerosol opical depths, dereved from the radiation intensity measurements for these wavelengths at different times (different solar zenith angles) on 20th November, 1998. The aerosol optical depths on ghis day are 0.75, 0.25, 0.097 and 0.048 for 368, 500, 675 and 778 nm wavelengths respectively. In these derivations it is assumed that the total attenuation in the atmosphere is due only to the presence of aerosols and the attenuation due to Rayleigh scattering, Ozone absorption and wqter vapour absorption is negligible. In reality, this may not be the case and this may be the reason that the optical depths at 368 run seems quite high and a substantial part in these values may be due to some other factors specially, the Rayleigh scattering.

NPL has been for pursuing the aerosol optical depth measurement program at Antarctica since 1987. The earlier results (Singh et al, 1992) are compared with the present results and it is found that optical depths have increased since 1990 to 1998. The optical depths at 368 and 500 nm were estimated to be 0.25 and 0.10 in 1990, while they have been estimated to be 0.75 and 0.25 in 1998. This is quite a substantial increase in the aerosol optical depths within eight years of time.

Conclusions

The variation of MED and solar radiation intensities at 280, 290, 300 and 310 nm are studied on daily, monthly and yearly basis . It is found that the MED and spectral intensities do not go very high during Ozone hole period. It is also observed that the MED values and global UV intensity values show the anti correlation with total column ozone values. The break of this anti correlation, as shown by Hanjura and Singh, 1995, for the direct intensity measurements on certain occasions, is not seen in the case of MED and global intensity values. The aerosol optical depth for 1998 are quite high compared to those earlier reported for 1990.

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REFERENCES

Hanjura A K and R. Singh, 1995, 'UV-B' radiation intensity measurements at Antarctica, Deptt. of Ocean Dev Report 8, 17-34.

Hanjura A K, S D Sharma M C Sharma and B N Srivastava, 1988, 'Turbidity and Ultra violet radiation measurements at Antarctica during VI Indian Scientific Expedition, NPL Res. Rep No 88 - C6 0002.

Singh R, P K Pasricha, M C Sharma and B N Srivastava, 1992, 'Multi wavelength measurement of atmospheric turbidity and determination of fluctuations in the total wavelength in Antarctica, Atmos. Environ., 26A, 525 - 530.

Srivastava, B N and M C Sharma, 1979, 'Design and development of solar UV-B photometer, RSD Tech Rep No. 101, NPL, New Delhi.

FIGURE CAPTIONS

Fig. 1. Diurnal variation of minimum erythemal doses at Antarctica, Leh, Hanle and Delhi.

Fig. 2. Day to day varation of local noon values of MED/30 min and the total column ozone content values for the month of Oct 98.

Fig. 3. Day to day varation of local noon values of MED/30 min and the total column ozone content values for the month of Nov.98.

Fig. 4. Day to day varation of local noon values of MED/30 min and the total column ozone content values for the month of December, 1998.

Fig. 5. Month to month variation of monthly average values of local noon MED/30 min. and the total column ozone contents from January to December, 1998.

Fig. 6. Month to month variation of monthly average values of local noon radiation intensity values of 310 nm and the total column ozone content from January to December, 1998.

Fig. 7. Langley curve fitting for 368 nm intensities between Log I and Sec chi (secant of solar zenith angle) values on 20^{th} November, 1998.

Fig. 8. Langley curve fitting for 500 nm intensities between Log I and Sec chi (secant of solar zenith angle) values on 20^{th} November, 1998.

Fig. 9. Langley curve fitting for 675 nm intensities between Log I and Sec chi (secant of solar zenith angle) values on 20^{th} November, 1998.

Fig. 10. Langley curve fitting for 778 nm intensities between Log I and Sec chi (secant of solar zenith angle) values on 20^{th} November, 1998.

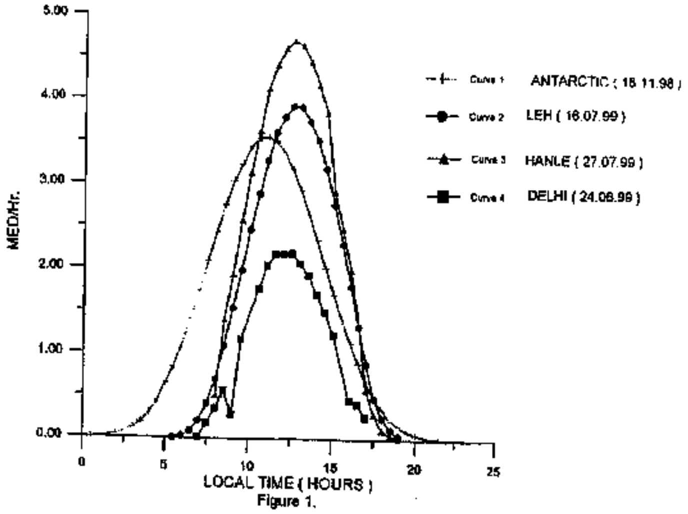
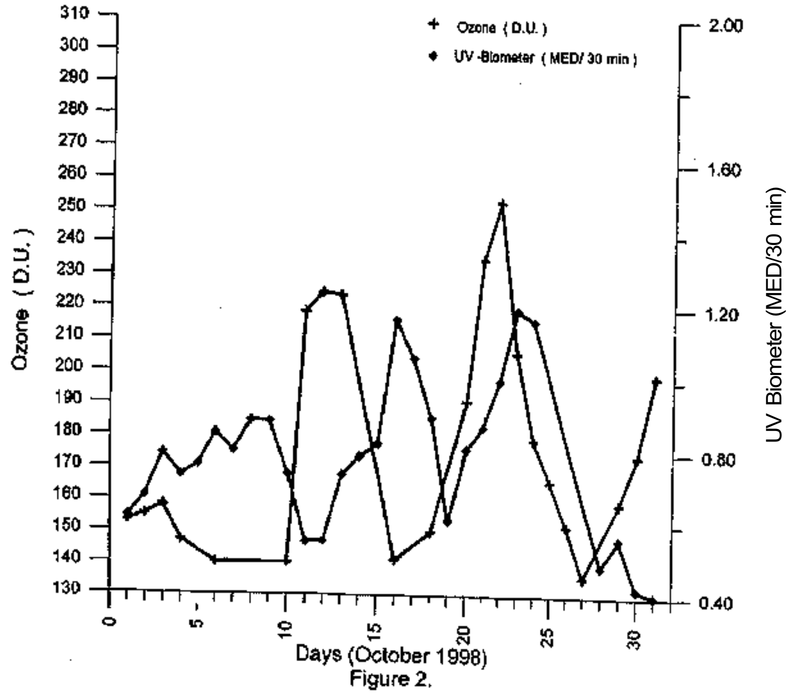


Figure 1.



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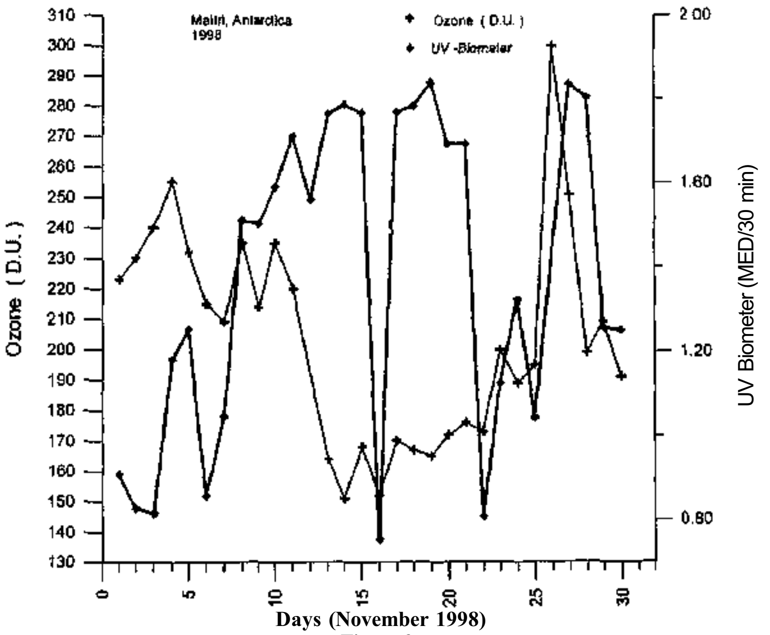

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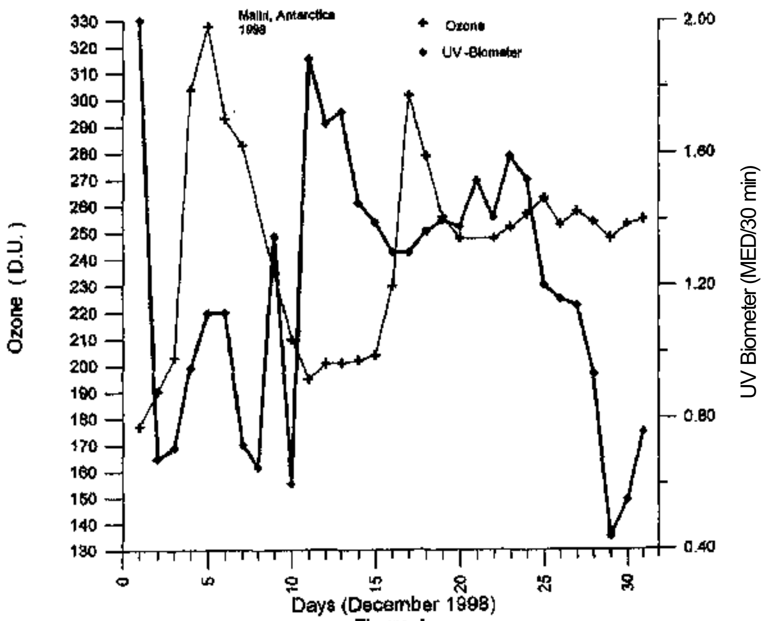

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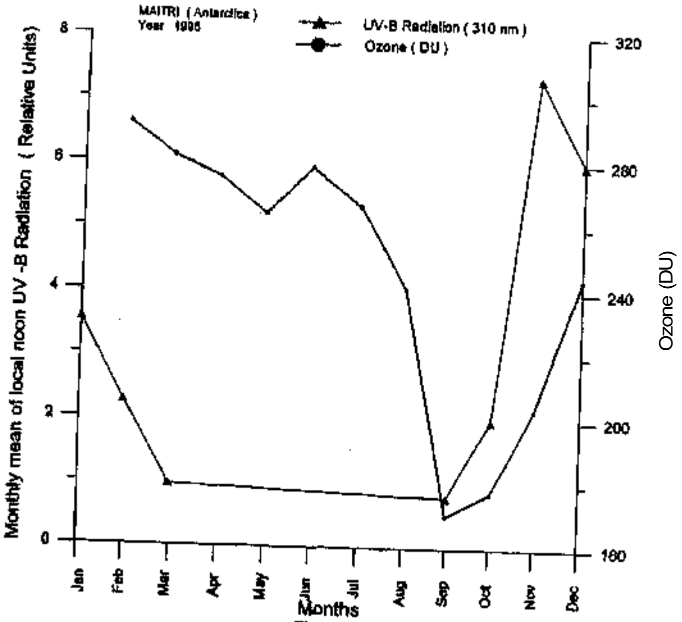
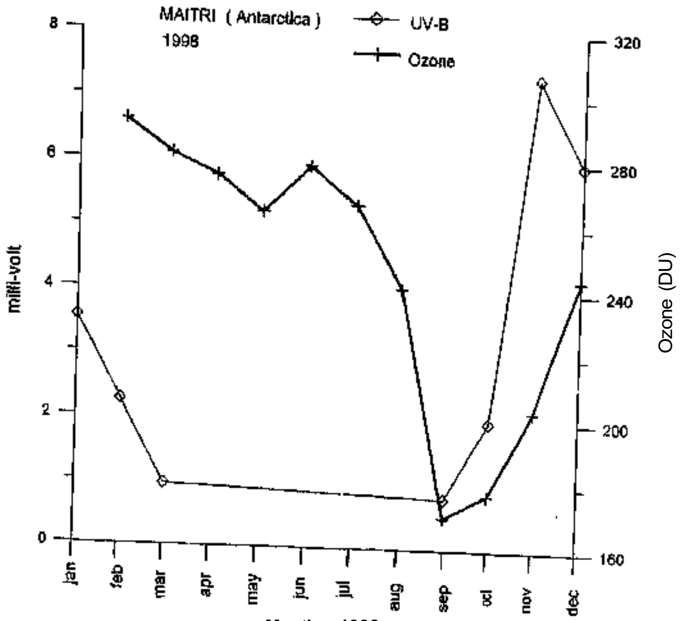


Figure 5



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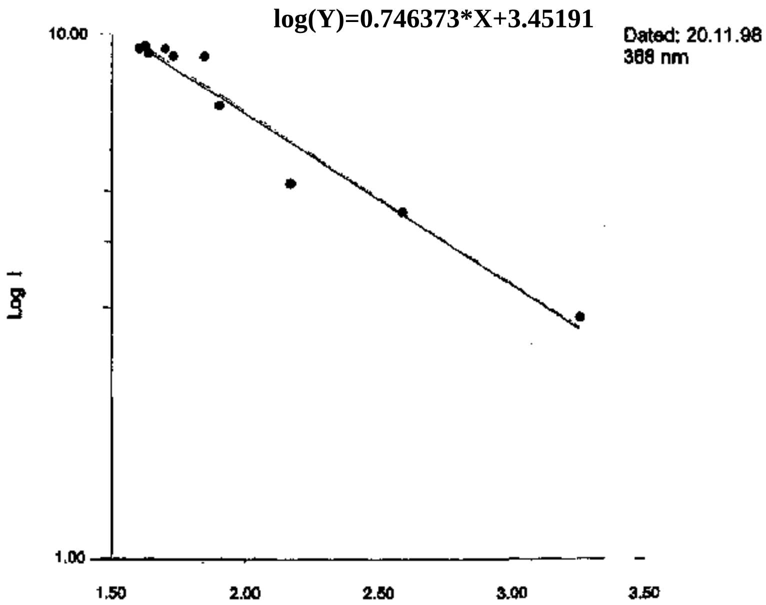

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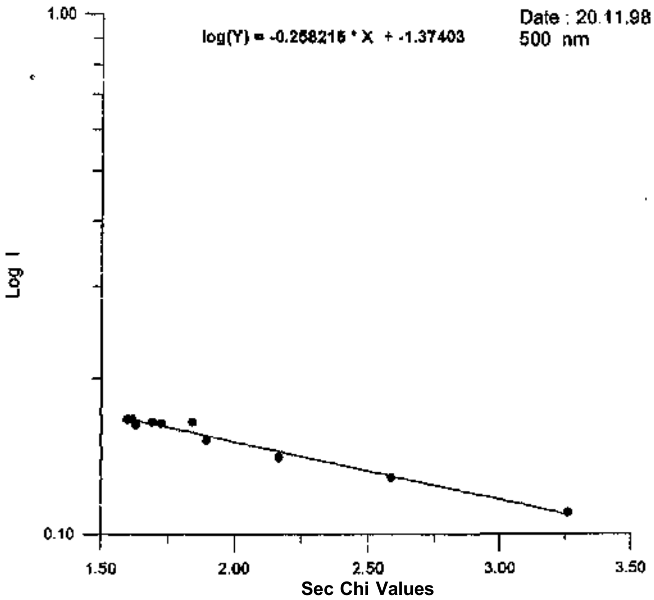

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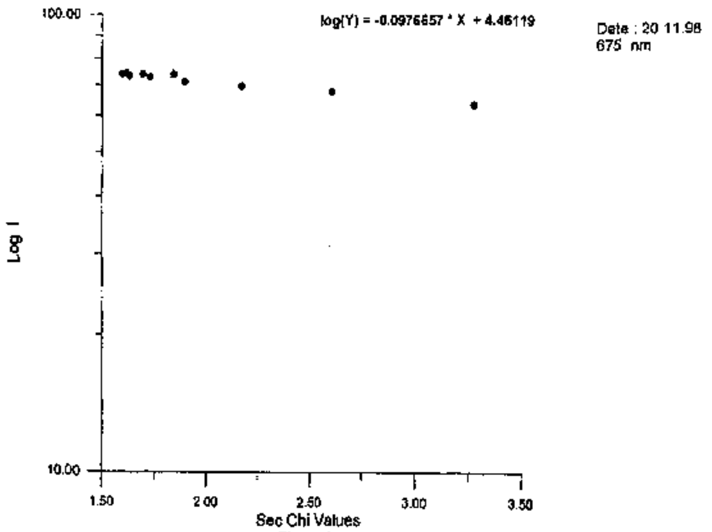

Figure 9.

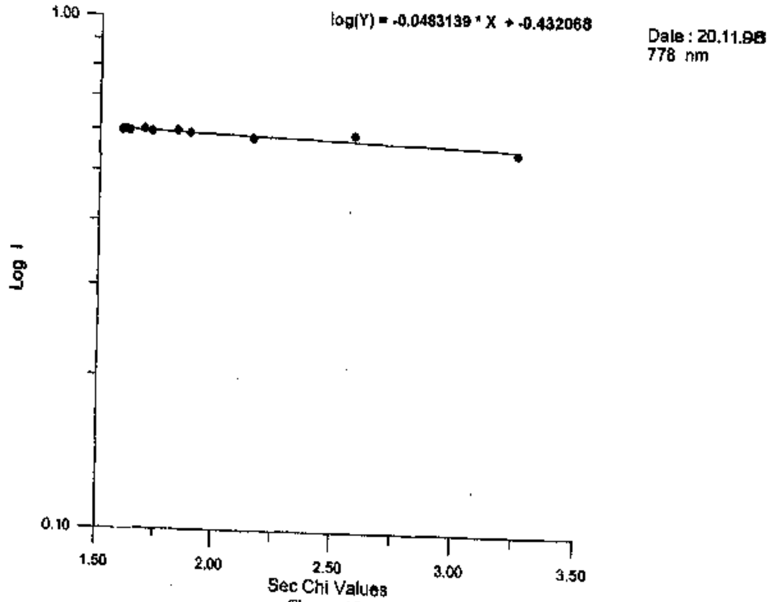

Figure 10.