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# Spectral Changes of Paper Exposed to Ambient Solar Radiation

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## Abstract

Solar radiation is known to be responsible for the photodegradation of materials including works of art and artefacts in the outdoor environment. Paper is one of the most light sensitive materials, because light can cause its darkening and fading. Damage goes beyond visual alteration by attacking the physical structure of paper, causing weakening and embrittlement. Ultraviolet (UV) radiation is hazardous and its damage is cumulative. Such effect can also occur in shaded rooms, due to the combined action of artificial and natural light sources. Thus, a better knowledge of UV radiation effect on paper would help both cultural heritage and paper manufacturing techniques. The present pilot study aims to analyse spectral absorbance changes in paper sheets exposed to ambient solar radiation in Rome during a field campaign held in July 2006. Ambient solar UV doses were recorded by means of spectral and broad band instruments. Results show that the absorbance changes were significant at wavelengths below 400 nm and that photodegradation proceeded faster during the first hours of exposure. A multivariate analysis taking into account wavelengths between 290 and 325 nm, paper sheets absorbance changes and the corresponding absorbed doses is carried out and preliminary results are presented. Possible archeometric applications are also proposed.

## Introduction

The role of solar radiation in the photodegradation of materials is known [1]. Efforts have been recently devoted to study the effects of radiation on works of art, mainly on library materials [2]. The Laboratory of Environmental Chemistry of the Chemistry Department (University of Rome "La Sapienza") has recently studied the effect of artificial solar light on paper [3], showing that deterioration is already visible after 150 hours of artificial exposure at 310 nm, using a spectral irradiance of 0.6 W $m^{-2}$ $nm^{-1}$ under controlled temperature (45°C) and relative humidity (58%).

The Solar Radiometry Observatory of the Physics Department (University of Rome "La Sapienza") has a deep experience in measuring ambient solar UV radiation by means of a Brewer Spectrophotometer and a YES UVB-1 broad-band radiometer. Both instruments can provide spectral and/or global UV irradiance at surface. In addition a reliable quantification of UV exposure of differently oriented surfaces can be obtained from ambient UV data coupled with those derived by polysulphone (PS) dosemeters [4].

A field campaign was performed in July 2006 by exposing some paper sheets on horizontal plane to ambient solar radiation nearby the UV instruments. The change in paper absorbance (? A) between 190 and 900 nm was measured and used as an indicator of its photodegradation. Simultaneously UV doses absorbed by paper were measured using PS dosemeters located below paper sheets in order to quantify the amount of UV radiation passing trough the paper.

## Materials & Methods

Fabriano paper was used to build paper dosemeters (called PP dosemeter) which consisted of small rectangles of size 1.6 cm x 1.2 cm, attached on plastic badges of size 3 cm x 3 cm. Six PP dosemeters were exposed to ambient solar radiation during daylight hours under different sky conditions in July 2006 with air temperature and relative humidity ranges 25°C-35°C and 35%-65% respectively. PP dosemeter n.1 was exposed for the entire period of the field experiment (more than 80 hours, 13 days) while the exposure of the PP dosemeter n.6 was about 8 hours (1 day). The other

4 dosemeters were exposed at different time intervals between the maximum and minimum exposure time. To understand the percentage of UV radiation passing through the PP dosemeter, PS dosemeters were attached under the badge and changed every day, following the well known PS methodology. Ambient UV doses were obtained by Brewer and YES UVB-1 irradiances. Pre and post exposure absorbances of PP and PS dosemeters were measured by a standard UV spectrophotometer (Perkin Elmer Lambda 5 UV-Vis double beam Spectrometer).

**Results**

Figure 1 shows the change in spectral absorbance of PP dosemeter n.1 measured at the beginning, at an intermediate stage (50 hours) and at the end (80 hours) of the exposure.

The main results can be summarised as follows:

- the absorbance spectral change of PP dosemeters occurs mainly below 400 nm (20% below 300 nm) and is not significant at longer wavelengths;
- the effectiveness of PP dosemeter absorbance decreases with the photodegradation increase;
- the degradation does not proceed after exposure when paper is let in the dark environment;
- the degradation is faster at the beginning of the exposure.

**Conclusions**

The presented pilot study consisted of a field experiment (held during summer 2006) using paper sheets exposed to ambient solar radiation under varying air temperature and relative humidity conditions. The aim was to analyse the paper damage after different UV exposure times, measuring absorbance changes as an indicator of photodegradation. Results showed that the absorbance spectral change occurs mainly below 400 nm, reaching 20% below 300 nm. Moreover the degradation, that does not proceed in the dark, is faster at the beginning of the exposure. A multivariate analysis was carried out confirming experimental results. Following [5], future efforts will be devoted to study possible archeometric implications, looking for correlations between paper absorbance changes and enzymatic activity in the cellulose.

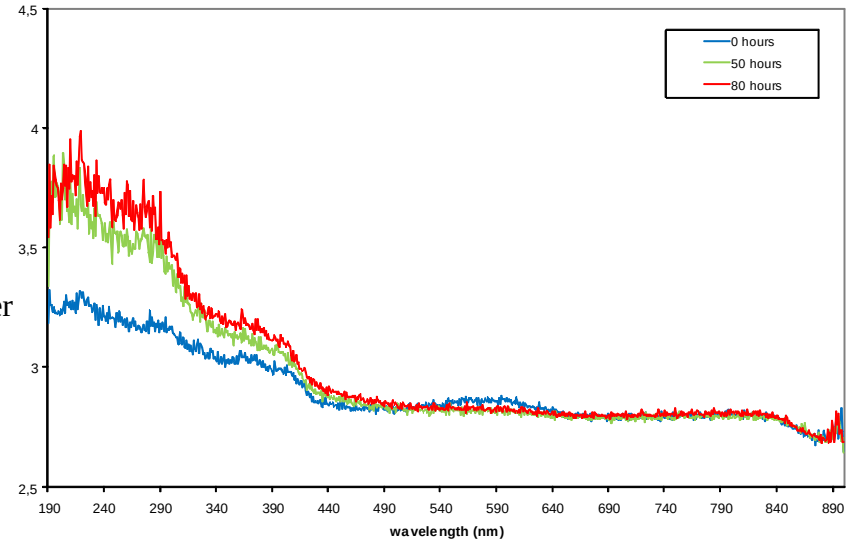


Fig. 1; PP dosemeter n.1 spectral absorbance change (vertical axis) after different time intervals of solar exposure

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