Effect of Light and Humidity on the Dosimetric Properties of Locally Manufactured Clear PMMA

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Summary: Effect of environmental conditions such as humidity during irradiation, or during post irradiation storage and different light conditions on the response of locally manufactured 3 mm thick clear PMMA dosimeter were investigated. The dosimeter showed a uniform response at almost all humidity conditions (12-92%) during irradiation. The response during post irradiation storage at different humidities also showed a stable response at least for two weeks after irradiation at almost all humidity conditions (12-92%); however at longer storage time fading takes place.

Introduction

We have recently investigated the dosimetric properties of some locally manufactured polymethylmethacrylate (PMMA) sheets [1-4]. PMMA sheets which are locally manufactured in Pakistan under the trade name of Plastiglass, are available at very low cost and can possibly be used as radiation dosimeter for sterilization of medical products and for food irradiation applications [5-7]. The response of PMMA dosimeters to radiation is often dependent on environmental factors and some effects due to environmental factors such as temperature and relative humidlity, have been reported [3,8,9]. In some cases these factors can have serious consequence for use of clear PMMA as radiation dosimeter.

The objective of the present investigation was to study the effect of different light conditions (direct sunlight, diffuse sunlight and fluorescent light) as well as different humidity conditions commonly encountered at radiation processing plants on the response of locally manufactured 3 mm thick clear PMMA dosimeters.

Materials and Methods

3 mm thick clear PMMA sheets manufactured by Pak Poly Industries (PPI), Karachi were purchased from local market. The plastic sheets were cut into small stripes of 1 cm x4 cm dimensions which are suitable for spectrophotometric analysis. The radiation induced optical density was measured using Shimadzu model UV-160 or Varian model DMS-200 recording spectrophotometers. The irradiation of 3 mm thick clear PMMA was carried out using a cobalt-60 gamma-ray source (Issoledovatel, USSR) available at the Nuclear Institute for Food and Agriculture (NIFA), Peshawar. This radiation source was calibrated using ferrous sulphate (Fricke) solution [10].

Humidity Dependence Studies

Constant relative humidity conditions at 25°C were maintained by using corked 100 ml graduated cylinders containing 25 ml of saturated salt solutions. For these saturated salt solutions it has been reported [11,12] that at 25°C negligible amount of solute intrudes into the gaseous phase of the environment and that relative humidity varies very little within temperature between 0°C and 50°C.

For investigating the effects of relative humidity *during irradiation* the dosimeters were suspended in air in the 100 ml cylinders. Each cylinder contained 25 ml of desired aqueous saturated salt solution and the dosimeters were subjected to different relative humidity conditions (12-97%) for 2 weeks before irradiation followed by irradiation under the same relative humidity conditions. For each dosimeter the absorbed dose was 25 kGy. Immediately after irradiation, the dosimeters were removed from the cylinders and stored at 54% relative humidity until spectrophotometeric readout. The dose inside the cylinder was determined using Fricke solution [10].

To study the effect of relative humidity *during post-irradiation storage,* the dosimeters were stored at 54 % relative humidity for 48 hours before irradiation so that equilibrium water content in dosimeter could be established. All the dosimeters were irradiated at the same relative humidity conditions (54%). Immediately after irradiation, the dosimeters were stored under selected humidity conditions (12-97%) for different periods of time until spectrophotometric analysis. Absorbed dose in each case was 25 kGy.

Light Dependence Studies

The influence of commonly encountered light conditions on the response of 3 mm thick clear PMMA dosimeter was determined by irradiating the dosimeters to 25 kGy and exposing the dosimetric strips to different light conditions (fluorescent light, direct sunlight and diffused sunlight) during post-irradiation storage. The optical density was measured at 305 and 314 nm at different storage time.

Results and Discussion

Light Effects

One of the environmental conditions likely to affect the response of clear PMMA dosimeter is ambient light such as direct sunlight, diffuse sunlight and fluorescent light. Fig. 1 shows the influence of direct sunlight, diffuse sunlight inside a laboratory and fluorescent light on the response of 3 mm thick clear PMMA irradiated to 25 kGy.

The results indicate that exposure to diffuse sunlight inside a laboratory exhibited practically no effect on the response of dosimeter at both the wavelengths of analysis for a storage period of 8 hours. However, there was a pronounced effect of direct sunlight on the response of dosimeter throughout the exposure period of 8 hours. The reason for this profound influence of direct sunlight may be due to UV component of sunlight as well as increase in the temperature of dosimeter due to direct sunlight. The exposure of fluorescent light for 36 hours results in a slight increase in the response which is, however, negligible for practical purposes since such long continuous exposure is not likely to be encountered by these dosimeters during commercial irradiation.

These results are similar to those reported for 2 mm thick clear PMMA [3]. Several other workers have also reported the photosensitivity of clear PMMA dosimeter [13,14]. The UV light was found

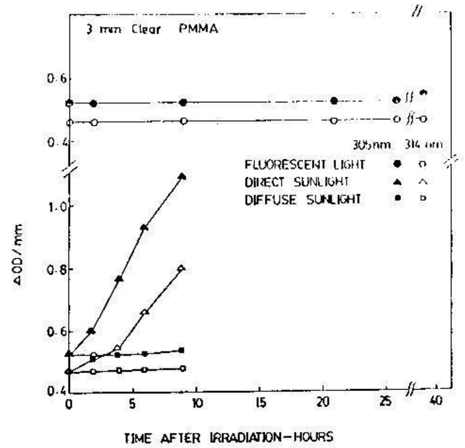


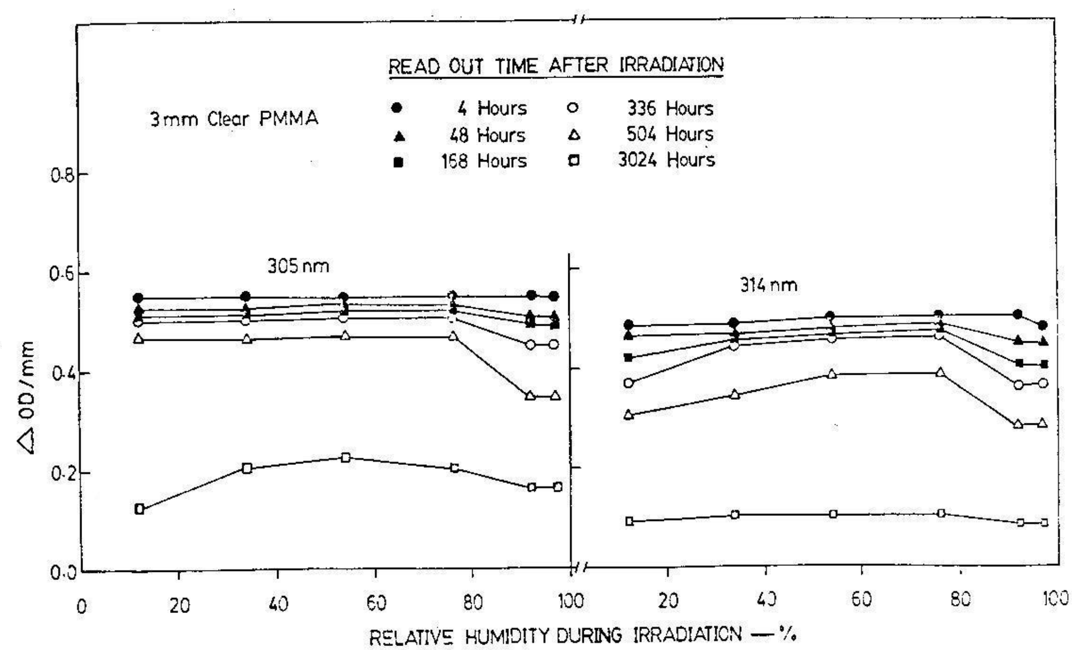
Figure 1: Effect of different light conditions on the gamma ray response of clear PMMA during post-irradiation storage. Absorbed dose 25 kGy.

to have the most damaging effects in clear PMMA dosimeter. Chadwick [15] ascribed this photosensitivity to the development of two species having strong optical absorbance in 300 nm and 265 nm regions. The effect was dependent on light spectrum as well as on dose of radiation and no simple correction could be found out. It is therefore suggested that exposure of irradiated dosimeter to direct sunlight should be avoided if useful dosimetry results are to be obtained.

Humidity Effects

Humidity effects were studied either during irradiation or during periods between irradiation and spectrophotometric analysis of dosimeter. The variation in relative humidity that a dosimeter may be exposed to both during irradiation and during post- irradiation storage, are mainly determined by local climatic conditions. The environmental conditions inside the irradiation room and micro-climate inside the radiation chamber can also vary. With this back ground, several experiments were conducted and the results are presented in Fig. 2 and 3.

The influence of relative humidity during irradiation is shown in Fig. 2. The results for spectrophotometric read out at 4 hours show that the response of the dosimeter is insensitive to different humidity conditions maintained at the time of irradiation. The situation is the same at both the wavelengths. However, for 314 nm at very wet conditions (*ca.* 97%), the response is slightly less. The results also reveal that there was a relatively small effect on the response of clear PMMA dosimeter for a storage period of 2 weeks (336 hours). At longer storage times, significant decrease in the response was observed especially for extended storage period of longer than 3 weeks (504 hours). The decrease in the response is larger at higher



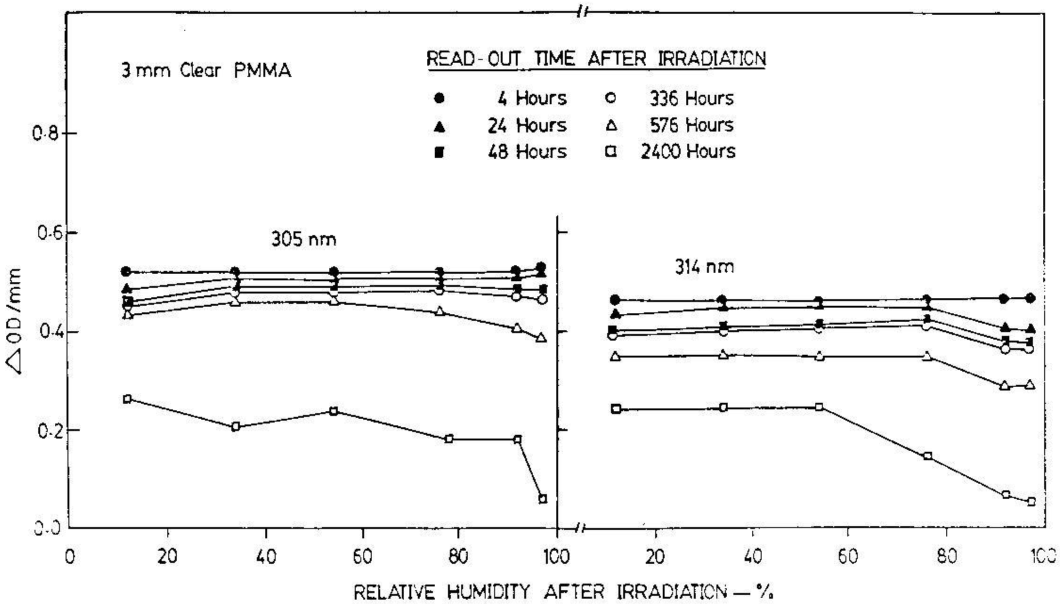


Figure 3: Effect of relative humidity during post irradiation storage on gamma ray response of clear PMMA. Absorbed dose 25 kGy.

humidities (> 76%). However, this decrease is relatively small under dried conditions (relative humidity < 76%). The behaviour of dosimeter's response relative to different humidities during storage time was similar at both the wavelengths (305 and 314 nm) used for spectrophotometric measurements. The results are consistent with the earlier observations that for short time storage, the response of clear PMMA is insensitive to the moisture content of PMMA [15] a feature which is different to the observations made for red PMMA [9].

In a second set of experiments the dosimeters after irradiation were stored at different relative humidities (12-97%) and changes in the response as a function of relative humidity during post- irradiation storage were measured at 305 and 314 nm as shown in Fig. 3. The Figure shows a significant effect of humidity over a storage period of 14 weeks, however, it is interesting to note that the stability of PMMA dosimeter is not affected for relative humidities between 12 to 92% over a storage period of more than 2 weeks (336 hours). The figure also shows relatively more fading at humidity conditions above 70% for longer storage times.

Exposure to humidity conditions for extended period of time considerably reduced the response. The results indicate that the stability pattern found at 305 and 314 nm are almost similar. Chadwick [15] earlier reported that oxygen diffusion, which is the main cause of fading in PMMA, is dependent on the moisture content of PMMA. The fading is faster for wet conditions and slower for dry conditions. Therefore it was proposed that dry clear PMMA should be preferred because of post-irradiation stability. It appears that for our sample moderate humidity conditions below 76% are also suitable showing resonable post-irradiation stability.

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