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Spectrophotometric Study of Polymeric DyesGels After a Gamma Irradiation Process for its Possible Use as a Radiation Dosimeter

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ABSTRACT

This work aims to evaluate a dosimetric system composed of green malachite supported in agarose. Previous work showed that solutions of green malachite irradiated at 1 to 40 kGy present a linear behavior. This system is a gel composed of green malachite (2.5×10^{-3} M), sodium benzoate (1%), and agarose (1%) that was exposed tovarious doses of gamma irradiation. The irradiated systems were measured with a UV-V is spectrophotometer at 619 nm. Experimental parameters (such as dose rate, doses, and temperature) were controlled and optimized for reproducible and reliable results. More studies are needed to propose a dosimeter in the system in the range of 1.8 to 4.0 kGy.

1. Introduction

Several reliable dosimeters can measure absorbed doses of ionizing radiation: organic compounds in solid state [1, 2], radiochromic dye films and solutions [3], aqueous aromatics organic solutions [4], and more. We previously studied-via UV-V is spectroscopy technique-the dose response of organic dye solutions under gamma irradiation in the range of kGy. Our results showed that organic dye solutions could be used as dosimetric systems at low and room temperatures. Next, we propose something that can support organics dyes. In this work, we prepared polymeric gels of agarose colored with green malachite. The use of gels for radiation dosimetry was first suggested by Day and Stein in 1950. Radiation was used to produce color changes in gels containing dyes [5]. Gels such as gelatin, agarose, polyvinyl alcohol (PVA), and more were analyzed after gamma irradiation experiments; they had only limited advancement of gel dosimetry due to a shortrange of dose-response linearity [6]. This work aims to study the doseresponse of prepared polymeric gels (colored with green malachite and added sodium benzoate) via spectrophotometric means after gamma irradiation at several doses.

2. Materials and Methods

2.1 Dyespolymeric Gels

Polymeric dye gels (PDG) were prepared using aerated aqueous solutions of: (1) green malachite ($C_{23}H_{25}ClN_2$) (2.5×10^{-3} M), (2) 1% of sodium benzoate(C_6H_5COONa); and (3) 1% of agarose (polysaccharide of D-galactose and 3,6-anhydro-L-galactopyranose). The mixture was heated (at approximately 60°C) in a microwaveoven to solvate the reagents. Approximately 4 mL of the mix was placed in a plastic spectrophotometric cell with a 1 cm optical path length.The gel formed when the mixture reached room temperature. To build the PDG's calibration curves, various concentrations of green malachite were used (2.7×10^{-4}, 5.5×10^{-4}, 8.2×10^{-4}, 1.1×10^{-3}, 1.4×10^{-3}, 1.6×10^{-3}, and 1.9×10^{-3}M). All compounds were the highest purity available, and they were used without further purification. Milli-Q water was employed in all the experiments.

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2.2 *Irradiation Procedure*

For dose-response studies, plastics pectrophotometric cells containing PDG were exposed to gamma irradiation from a ^{60}Co gamma-ray source (a Gamma beam 651 PT facility at the Instituto de Ciencias Nucleares, UNAM). The samples were irradiated at various doses. The absorbed doses were between 0.4 and 12.5 kGy at a fixed position with a dose rate of 200 Gy/min. The dose rate was determined using the ferrous ammonium sulfate-cupric sulfate dosimeter [7].

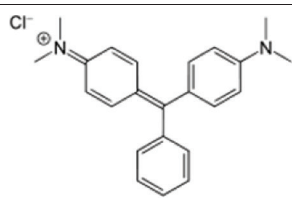
2.3 *Analysis after Irradiation Procedure*

After irradiation, the plastic spectrophotometric cells with PDG were analyzed using the UV-V is spectrophotometer Varian Cary 100 Scan at 619nm.

3. Results and discussion

The gel's color depends qualitatively and quantitatively on the concentrations of green malachite. A linear relationship was found in the systems used (Table 1). After obtaining

Table1: Linear range data of the absorbance–concentration relationships and the molar extinction coefficients of various PDGs.

Dye	Molecule structure	Maximum wavelength (nm)	Concentration range (M)	Molar extinction coefficient ($M^{-1}cm^{-1}$)	R^2
Green malachite ($C_{23}H_{25}ClN_2$)		619	2.7×10^{-4}–1.9×10^{-3}	157.74	0.9644

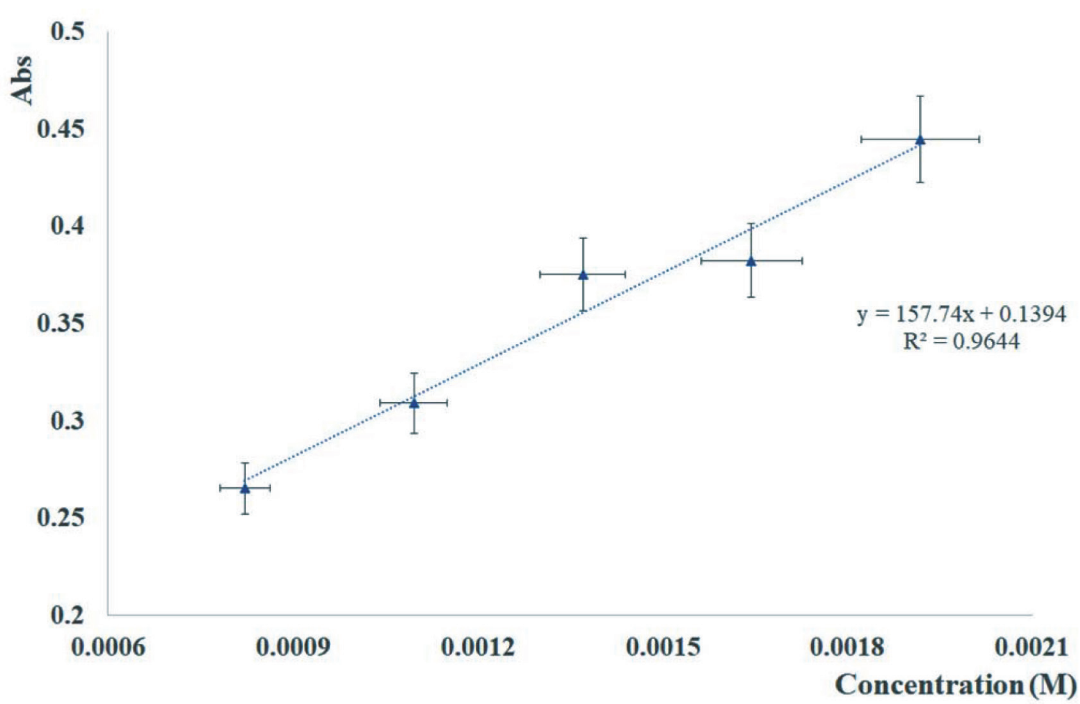


Figure 1: The green malachite calibration curve (2.7×10^{-4}–1.9×10^{-3}M).

the molar extinction values (Figure 1), the concentration of PDG selected for the radiolysis experiments was 2.5x10^{-3}M.

3.1 Gamma Irradiation of Polymeric Dyes Gels

In this work, we added sodium benzoate to an agarose polymeric system to function as a captor of the OH radicals produced by the radiolysis of the water and to increase the dose-response linearity's range. Series of PDGs were irradiated at various absorbed doses (0.4, 0.6, 0.8, 1.0, 2.0, 2.5, 3.0, 5, 7.5, 10, and 12.5 kGy) at room temperature. The coloring of the gels decreases as the radiation dose increases (Figure 2), which is why the gels can be measured via UV spectrophotometry. The gel response in the 4 to 12.5 kGy dose range is nonlinear, and as expected, applying a linear calibration resulted in poor profiles, particularly at high doses (Figure 3). The linear curve was observed from 1.8 to 4.0 kGy with a correlation coefficient of 0.98301 (Figure 3).

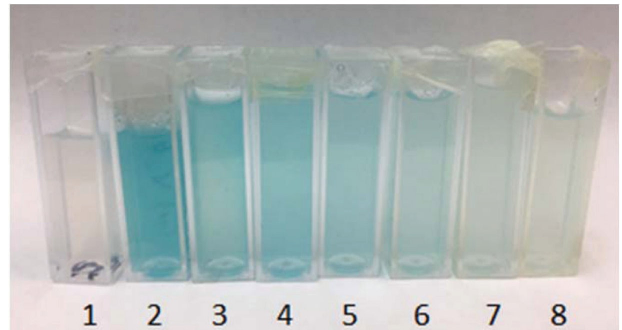


Figure 2: The green malachite color decreases as the radiation dose increases. Plastic cell No.1 has agarose without green malachite (control); plastic cell No. 2 has a 1 kGy dose adsorbed; plastic cell No. 3 has a 2.0 kGy dose adsorbed; plastic cell No. 4 has a 3.0 kGy of dose adsorbed; plastic cell No. 5 has a 5.0 kGy dose adsorbed; plastic cell No. 6 has a 7.5 dose adsorbed; plastic cell No. 7 has a 10 kGy dose adsorbed; and plastic cell No. 8 has a 12.5 kGy dose adsorbed.

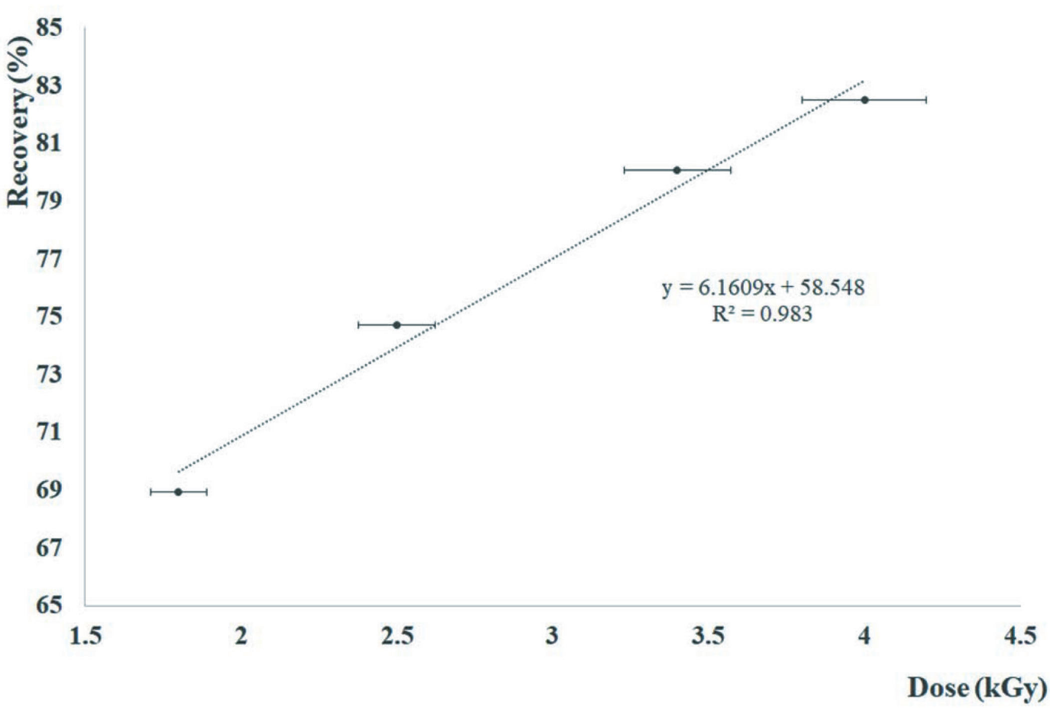


Figure 3: The linear range interval of the dose–response curves irradiated at room temperature.

4. Remarks

We studied how green malachite in an agarose gel responded to gamma irradiation. The dose-response curve showed linearity from 1.8 to 4 kGy for the systems under study. These systems could be used in a wide range of dosimetry studies, such as studies on food and on clinical material-radiation treatment. Moreover, their preparation and measure-ments are fast, inexpensive, and easily measured via UV-V is spectroscopy. The techniques for handling the dosimeters present no unusual problems. However, more parameters should be evaluated for their use as dosimeters.

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