Radiolysis of Commercial Dyes in Aqueous Solutions to Produce Dosimeters for Gamma Dosimetry

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Abstract: The usability of aqueous solutions of SR C4BLN and SGY CRL dyes; as secondary dosimeter was confirmed. All samples were irradiated by Co^{60} γ-source in the range 0-10^5Gy. Absorbance of solutions was noted at λ_{max} for pre and post irradiation stages. The λ_{max} of Red and Yellow dyes were 545nm and 448nm respectively. The absorbance% and the %discoloration of each dye were determined. Sample solutions showed a gradual decrease in Absorbance% and increase in %age discoloration versus absorbed doses.

Keywords: Chemical dosimeters, SR C4BLN, SGY CRL, dosimetry, Absorbance%, %age discoloration.

1. INTRODUCTION

Ionizing radiations can cause chemical and physical changes in the exposed material [1, 2]. The search for inexpensive and user friendly dosimeters is an active research area for the physicists and chemists as well. There are numerous dosimeters such as ionization chambers, thermo-luminescent detectors (TLDs), radiographic films, silicon diode dosimeter, alanine dosimeter, plastic scintillators, diamond dosimeter, gel dosimeter, Fricke dosimeter and so forth, and are used for the evaluation of ionizing photons. Dye dosimeters are well documented and different researchers used various colors such as Congo red [3], brilliant green [4], anionic triphenyl-methane dye solutions [5], chlorantine fast green BLL [6] and methyl red [7] to prepare dye dosimeters. However, in this study the suitability of commercial Sandalfix Red C4BLN (SR C4BLN) and Sandalfix Golden Yellow CRL (SGY CRL) dyes were tested to be used as dye dosimeters. It is well known phenomenon that the ionizing radiations cause bleaching of the dye in aqueous solutions. This bleaching of the chosen dye can be used for dosimetry, since the decomposition of the dye linearly depends upon the amount of dose absorbed [3]. To explore the synthetic commercial dye that can be used as a dosimeter is really a challenge. It is known that commercial dyes contain pigmentations (coloring substance), which are used to impart color. However, these dyes also have other uses like as chemical dosimeters for high gamma radiation doses [4]. The corresponding chemical changes caused to the irradiated aqueous dye solutions by the gamma radiations can be observed by the respective fading of the dye and hence is the measure of the absorbed dose of the incident γ-radiations [5]. The dyes used in this study are commercial and cheap dyes, namely, SR C4BLN and SGY CRL, available with the Sandal Dyestuff Industries Pvt. Ltd. Faisalabad. Both of the narrated dyes follow the Beer's law so the dosimetric calculations were made without any qualm [1, 2].

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2. MATERIALS & METHODS

SR C4BLN dye (MW: 1033.5amu) and SGY CRL dye (MW: 1070amu), were used without further purification. 1 gram of each dye was weighted by Electrical Balance Sartorius, Ag Gottingen BL2105 (Germany) and was dissolved in 1 Liter deionized water. The ready solutions had concentration 1gm/L at pH 7.0 measured by pH-meter (Hanna 8417). Owing to high solubility of the dyes in such polar solvents, these were readily dissolved at room temperature 30°C by a glass stirrer. Different concentrations of the dye solutions were prepared such as C_1=1 gm/L, C_2=0.5gm/L and C_3=0.25gm/L. The prepared samples were preserved at room temperature (30°C). The dyes have absorption band maxima i.e., λ_{max}=545nm and 448nm respectively, determined by UV-Visible spectrophotometer (Lambda 25 1.27, PerkinElmer, USA). The absorbance (A) of the samples was measured at λ_{max} of both the dyes.

ISSN: 1814-8085 / E-ISSN: 1927-5129/12

2.1. Irradiation of Samples

Co^{60} gamma radiation source from Pakistan Radiation Services (PARAS) Lahore (Pakistan), having dose rate 0.4kGy/hour was used for irradiation. Irradiation of solutions was carried out as follows: 5ml of solution was taken in a plastic vial of internal diameter 1.03cm and thickness 0.18cm with fit in plastic stoppers. The gamma radiation dose range was selected as 0-10^5Gy. The control samples were un-irradiated. Low dosimetry was done by the γ-radiation doses in the range of 10^2-10^3Gy. For those of intermediate doses the range of γ-radiation doses was 10^3-10^4Gy. Moreover, for high-dose dosimetry, the range of 10^4-10^5Gy was chosen. The samples were irradiated for predetermined time according to desired doses. The structure diagrams of both the dyes are shown in Figure **1** & **2** respectively.

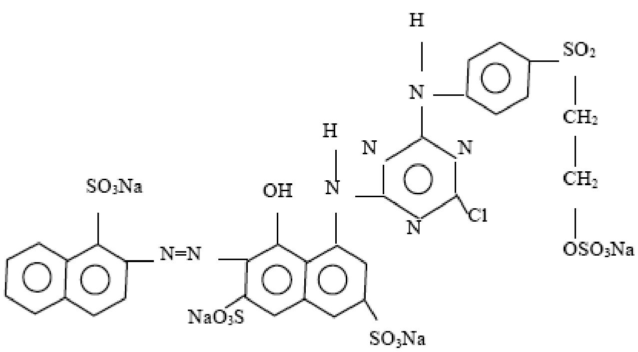

Figure 1: Structure diagram of SR C4BLN.

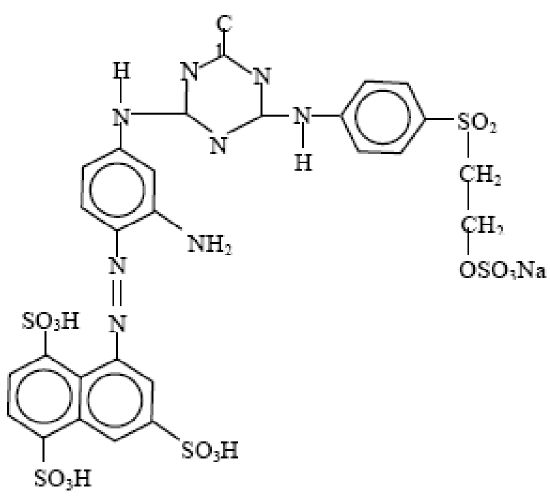

Figure 2: Structure diagram of SGY CRL.

3. RESULTS & DISCUSSION

The optical wavelength (λ_{max}) and absorbance (A) of the samples were measured with a double beam spectrophotometer using a band pass setting of 1mm. the solutions were held in the object beam in quartz glass, 10mm path lengths cuvette, with the reference beam cuvette containing the deionized water.

The gamma radiation response for the aqueous solutions of the Yellow and Red in terms of the %age discoloration and Absorbance% was determined [7, 8].

$$\%\text{age discoloration} = [(A_o - A_x)/A_o] \times 100 \quad (1)$$

$$\text{Absorbance}\% = [A_x/A_o] \times 100 \quad (2)$$

Where, A_x *and* A_o represent the absorbance of irradiated and non-irradiated dye solutions, respectively.

The found values of the %age discoloration and absorbance% and used nomenclature are given in the Table **1** and **2** respectively.

4. CONCLUSION

The aqueous solutions of the SR C4BLN and SGY CRL dyes were found satisfactorily useable as passive dosimeters in the range 10^3-10^5Gy i.e., they have shown very good response in the “Intermediate dosimetry and High dosimetry”. Moreover, the less concentrated solutions such as C_3 have shown more accuracy in the dosimetric calculations as compared to the high concentrations C_1 and C_2. It was found that less concentrated solutions of both the dyes were suitable for dosimetery in the range 0-10^3Gy while for high concentrated solutions; the usable gamma dosimetry range was extended up to 10^3-10^5Gy. Table 1 depicts that the sample solutions of SR and SGY have shown a gradual decrease in Absorbance% with respect to the absorbed doses. Also the %age discoloration increases as the irradiation phase increases. Hence, the selected synthetic dyes SR C4BLN and SGY CRL have been confirmed for the dosimetric calculations within the dose range 10^3-10^5Gy.

5. FUTURE RECOMMENDATIONS

For future work, one may use these dye in some other solvents like Ethanol, Benzene etc. rather than the deionized water, to check the behavior of these dyes. Moreover, the pH of the sample solutions, being a great factor to affect the response of the solutions, should also be carefully handled to check its effect on the selected dyes.

Table 1: Percentage (%age) Discoloration of the selected dyes

Name of the Dye	Mean λ_{max} (nm)	Dosimetric Phase	Concentrations	Mean Absorbance (A)	Percentage Absorbance (%A)	%Age Discoloration
SR	545	Low ($0\text{-}10^3$Gy)	C_1=1g/L	3.314	91.916	-05.329
			C_2=0.5g/L	2.211	87.434	-12.566
			C_3=0.25g/L	2.201	87.891	-12.109
		Intermediate ($10^3\text{-}10^4$GY)	C_1=1g/L	1.959	75.468	-45.573
			C_2=0.5g/L	0.818	31.428	-67.448
			C_3=0.25g/L	1.170	44.742	-53.481
		High ($10^4\text{-}10^5$GY)	C_1=1g/L	0.443	17.340	-87.375
			C_2=0.5g/L	0.177	06.734	-92.986
			C_3=0.25g/L	0.289	10.637	-89.838
SGY	448	Low ($0\text{-}10^3$Gy)	C_1=1g/L	2.496	96.075	-03.925
			C_2=0.5g/L	2.185	79.083	-20.917
			C_3=0.25g/L	2.134	90.834	-09.166
		Intermediate ($10^3\text{-}10^4$GY)	C_1=1g/L	2.524	98.562	-02.806
			C_2=0.5g/L	1.359	52.466	-47.534
			C_3=0.25g/L	1.749	67.693	-32.307
		High ($10^4\text{-}10^5$GY)	C_1=1g/L	1.795	69.546	-03.454
			C_2=0.5g/L	0.675	17.340	-73.587
			C_3=0.25g/L	1.795	42.794	-30.454

Table 2: Nomenclature

Terms used	Description
SR	Sandalfix Red
SGY	Sandalfix Golden Yellow
A_x	Absorbance of irradiated samples
A_o	Absorbance of un-irradiated samples
Gy	Gray

ACKNOWLEDGEMENTS

The authors feel great zeal of pleasure to thank the Director, Punjab Institute of Nuclear Medicine (PINUM), Faisalabad (Pakistan) for providing the laboratory facilities and to Mr. Kafayat-Ullah, Pakistan Radiation Services (PARAS), Lahore (Pakistan) for providing the radiation facility and Mr. Imran, Mr. Tauqeer, Mr. Kaleem Hussain, Mr. Rashid Hussain and Mr. Wajid Hussain are also acknowledged in laboratory accessories managements.

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Received on 02-04-2012 Accepted on 29-04-2012 Published on 19-05-2012

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