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Gamma Radiation Effect on Commercial Reactive Dye in the Range 0-100KGy Using the Idea of the De-Coloration Factor and Extinction Coefficient

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Abstract: In this study the usability of aqueous solutions of SR C4BLN and SGY CRL dyes; as secondary dosimeter was checked using the novel idea of de-coloration factor and extinction coefficient. 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%, extinction coefficient and %age of de-coloration factor for each dye were determined. The results showed a gradual decrease in Absorbance% and extinction coefficient while decrease in %age of de-coloration factor with the increase in absorbed dose which confirms the said dyes as secondary dosimeter in stable and safe mode.

Keywords: Chemical dosimeters, SR C4BLN, SGY CRL, dosimetry, Absorbance %age, extinction coefficient, de-coloration factor.

1. INTRODUCTION

Ionizing radiations can cause chemical and physical changes in the exposed material [1-7]. 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 [8], brilliant green [9], anionic triphenyl-methane dye solutions [10], chlorantine fast green BLL [11] and methyl red [12] 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].

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

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spectrophotometer (Lambda 25 1.27, PerkinElmer, USA). The absorbance (A) of the samples was measured at max of both the dyes.

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 Figures **1** & **2** respectively.

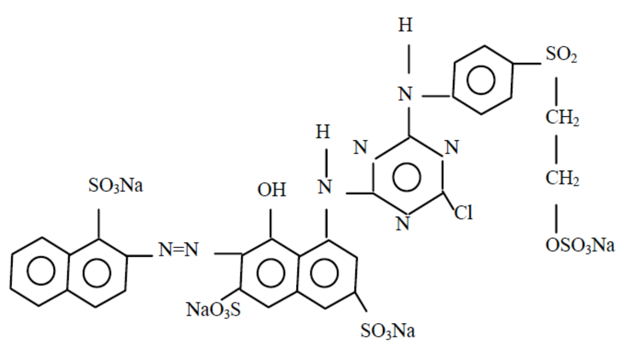

Figure 1: Structure diagram of SR C4BLN.

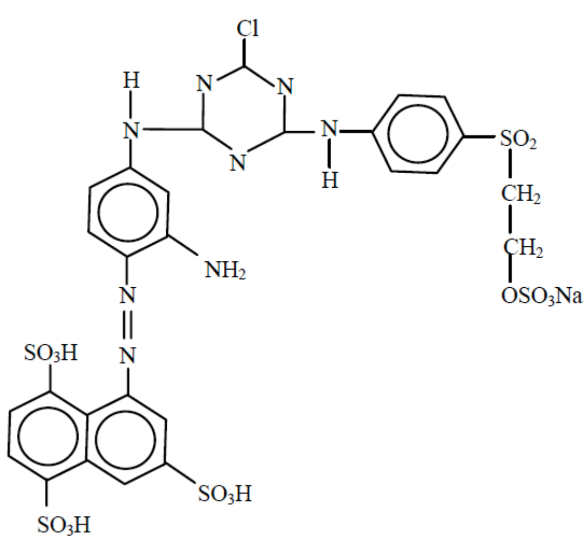

Figure 2: Structure diagram of SGY CRL.

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 [12, 13].

%age of de-coloration = $[(A_o-A_x)/A_o]\times 100$ ……… (1)

Absorbance% = $[A_x/A_o]\times 100$ ………………….. (2)

Extinction Coefficient ε = A/Cl ………………….. (3)

Where, A_x *and* A_o represent the absorbance of irradiated and non-irradiated dye solutions, respectively. However, *"C"* stands for the concentration of the sample solutions and *"l"* represents the path length. The found values of the Absorbance %age and %age de-coloration for the selected dyes are shown in Table **1**. The Extinction coefficient of the selected dyes is shown in the Table **2**. Moreover the used nomenclature is given in the Table **3**.

4. CONCLUSION

SR with λ_{max} 545nm was found to be most suitable for Low dose at concentration order C_1=1g/L, C_3=0.25g/L and C_2=0.50g/L respectively, following standard decreasing orders of mean Absorbance 3.314, 2.201, 2.211; Absorbance %age 91.916, 87.891, 87.434 in Acidic phase of dye solution. %age of de-coloration for Acidic phase was found to be 92.88, 89.46, and 85.47 while %age of de-coloration for alkaline phase was found to be 92.32, 89.34 and 86.33.

As for as the SR dye is concerned, the extinction coefficient for Acidic phase was 7675.73, 3925.26, 3164.25 while for those of alkaline phase 10744.97, 5326.54, 3738.31 following the above said order of the concentrations.

While SGY with λ_{max} 448nm was found to be most suitable for Intermediate dose at concentration order C_1=1g/L, C_3=0.25g/L C_2=0.50g/L following standard decreasing orders of mean Absorbance 2.524, 1.749, 1.359; Absorbance %age 98.562, 67.693, 52.466; in Acidic phase of dye solution. %age of de-coloration for Acidic phase was 96.57, 80.42, 49.16 and %age of de-coloration for alkaline phase was 69.04, 49.61, and

Table 1: Absorbance %Age and %Age De-Coloration of the Selected Dyes

Name of the Dye	Mean λ_{max} (nm)	Dosimetric Phase	Concentrations	Mean Absorbance (A)	Percentage Absorbance (%A)	%age of De-coloration factor (Acidic)	%age of De-coloration factor (Alkaline)
SR	545	Low (0-10^3Gy)	C_1=1g/L	3.314	91.916	92.88	92.32
			C_2=0.5g/L	2.211	87.434	85.47	89.34
			C_3=0.25g/L	2.201	87.891	89.46	86.33
		Intermediate (10^3-10^4GY)	C_1=1g/L	1.959	75.468	55.70	53.72
			C_2=0.5g/L	0.818	31.428	33.29	31.55
			C_3=0.25g/L	1.170	44.742	46.10	46.94
		High (10^4-10^5GY)	C_1=1g/L	0.443	17.340	16.47	8.84
			C_2=0.5g/L	0.177	06.734	13.16	12.52`
			C_3=0.25g/L	0.289	10.637	2.836	17.48
SGY	448	Low (0-10^3Gy)	C_1=1g/L	2.496	96.075	94.33	97.93
			C_2=0.5g/L	2.185	79.083	70.99	87.29
			C_3=0.25g/L	2.134	90.834	92.59	89.06
		Intermediate (10^3-10^4GY)	C_1=1g/L	2.524	98.562	96.57	100.66
			C_2=0.5g/L	1.359	52.466	49.16	49.61
			C_3=0.25g/L	1.749	67.693	80.42	69.04
		High (10^4-10^5GY)	C_1=1g/L	1.795	69.546	75.95	63.07
			C_2=0.5g/L	0.675	17.340	30.19	19.12
			C_3=0.25g/L	1.795	42.794	51.97	42.53

Table 2: Extinction Coefficient of the Selected Dyes

Name of the Dye	Mean λ_{max} (nm)	Dosimetric Phase	Concentrations	Mean Absorbance (A)	Extinction Coefficient of Acidic solutions	Extinction Coefficient of Alkaline solutions
SR	545	Low (0-10^3Gy)	C_1=1g/L	3.314	3164.25	3738.31
			C_2=0.5g/L	2.211	3925.26	5326.54
			C_3=0.25g/L	2.201	7675.73	10744.97
		Intermediate (10^3-10^4GY)	C_1=1g/L	1.959	1884.57	2165.01
			C_2=0.5g/L	0.818	1506.01	1874.84
			C_3=0.25g/L	1.170	3913.40	5759.81
		High (10^4-10^5GY)	C_1=1g/L	0.443	557.30	357.53
			C_2=0.5g/L	0.177	316.58	414.27
			C_3=0.25g/L	0.289	240.76	2145.91
SGY	448	Low (0-10^3Gy)	C_1=1g/L	2.496	2164.44	2156.65
			C_2=0.5g/L	2.185	7376.53	8020.05
			C_3=0.25g/L	2.134	61362.80	57623.47
		Intermediate (10^3-10^4GY)	C_1=1g/L	2.524	2203.77	2212.51
			C_2=0.5g/L	1.359	4925.44	4498.12
			C_3=0.25g/L	1.749	52909.70	44172.86
		High (10^4-10^5GY)	C_1=1g/L	1.795	1733.32	1386.28
			C_2=0.5g/L	0.675	3024.68	1733.79
			C_3=0.25g/L	1.795	34189.83	27215.78

Table 3: 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

100.66 (structural damage). Moreover, for SGY, the extinction coefficient for Acidic phase was 52909.70, 4925.44, and 2203.77 while for those of alkaline phase 44172.86, 4498.12, 2212.51.

Both dyes are behaving in their respective dose ranges in accordance with the radioactive decay law and Beer's law, when dye solution is switching from alkaline phase to Acidic phase which confirms the internal structure changes with respect to the change in color with applied radiation dose.

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.

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