Gamma Dosimetric Response of Sandalfix Golden Yellow CRL Dye Solutions for Gamma Dosimetry Using Cs^{137} in the Range 0-1KGy

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Abstract: The effect of gamma radiation source (Cs^{137}) on the aqueous solutions of the Sandalfix Golden Yellow CRL dye was determined in the range 0-1kGy. λ_{max} of the dye was determined by UV/VIS spectrophotometer before the exposure of gamma radiations and was found to be 422 nm. Absorbance of the sample solutions was studied at λ_{max} of the dye at pre and post irradiation. It was determined that the Absorbance of the sample solutions was decreased with increasing absorbed dose. The exposed dye solutions were found to be discolored due to the structural changes in the dye solutions and the discoloration of the dye was found linear with respect to absorbed dose.

Keywords: Sandalfix Golden Yellow CRL, dosimetry, Cs^{137} gamma source, radiolytic bleaching.

1. INTRODUCTION

High energy radiations cause physical and chemical changes in the exposed materials whenever they interact with matter [1]. The procedure of determining the delivered quantity of ionizing radiations is called Radiation Dosimetry [2-5]. The narrow measurable dose range and large irradiation temperature dependence might result from recombination and transformation to other chemical forms of the radiation induced species [6]. The degradation of the dyes is initiated exclusively by •OH attack on electron-rich sites of the dye molecules. Various parameters that affect the efficiency of radiation induced degradation of dyes are; effect of radiation dose, oxygen, pH, hydrogen peroxide, added ions and dye classes [7, 8]. Linear relationship between color bleaching and irradiation doses is a well known radiation induced phenomenon [2-5].

The confirmation of the Sandalfix Golden Yellow CRL to be used for dosimetric calculations within the gamma radiation dose range 0-1kGy delivered by Co^{60}, was already reported [2-5] as the said dye obeyed Beer's Law. In order to observe the change in the λ_{max} and the dosimetric response of the dye with respect to the absorbed doses, the radiation source was changed to Cs^{137} but the irradiation dose range was the same from 0-1kGy. The application range depends on the concentration of the dye and the nature of the solvents used [9]. Bleaching of the dye in aqueous solutions by the ionizing radiations is a known fact now and is still an active research area for many researchers of the present era to produce dosimeters which should be inexpensive, easy to handle and have the capacity to work within the high dose ranges [10]. This bleaching property of the chosen dye makes the aqueous solutions of the dye able to be used for dye-dosimetry, since the decomposition of the dye depends linearly upon the amount of dose absorbed [11].

2. MATERIALS AND METHODS

Sandalfix Golden Yellow CRL (CI: 145A, MW= 1070amu) was available with the Sandal Dyestuff Industries Pvt. Ltd. Faisalabad, Pakistan. The structure of the dye is shown on the Figure **1**.

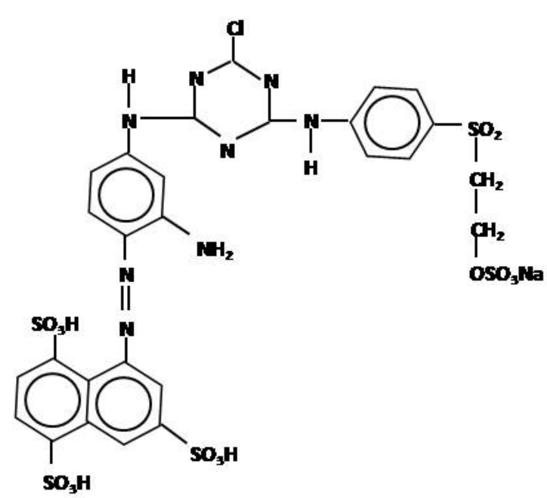

Figure 1: Structure diagram of Sandalfix Golden Yellow CRL.

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The electrical balance Mettler H35AR (USA) was used to weigh the dye and so 0.125 gram of the dye was dissolved in one liter demineralized water having electrical conductivity less than 1µSiemens/cm. The stock solution was set at pH 7 measured by pH-meter Milwaukee SM102 (Italy). Three concentrations of the dye solutions were prepared such as C_1=133.75µmol/L, C_2=66.88µmol /L and C_3=33.44µmol /L. Two sets of sample solutions were prepared namely, Acidic and Alkaline solutions. The pH of Acidic solutions was set as 4, 5 and 6 while those of alkaline solutions were set as 8, 9 and 10 respectively. Moreover, the solutions of pH 7 termed as "Control solutions", were kept chemically neutral and un-irradiated. The pH of the sample solutions was raised and lowered using 1 Molar solution of sodium hydroxide (NaOH) and hydrochloric acid (HCl) respectively. The sample solutions were preserved at room temperature (30^{o}C). The dye has absorption band maxima i.e., λ_{max}=422nm determined by T80 UV/VIS spectrophotometer. The absorbance (A) of all the samples was measured at this value of λ_{max}.

Cs^{137} gamma radiation source (having dose rate 660Gy/hour) from Nuclear Institute of Agriculture and Biology (NIAB), Faisalabad, Pakistan was used for irradiation purpose. All the samples were irradiated at a fixed position in the gamma flux with the help of a stand. Irradiation of solutions was carried out as follows: 5ml of solutions were taken in a Pyrex glass tube with fit in ground stoppers. The tubes were placed in the radiation field at a fixed position with the help of a stand and were exposed for predetermined interval of time [2-5, 10].

The response curves were plotted for pH versus absorbance (A) and dose (D) versus Absorbance (A) of the samples. Irradiation of samples with gamma rays showed the linear function with a positive slope between negative logarithm of Absorbance (A) and dose (D) [1]. The effect of gamma ray interaction with dye is to reduce absorption coefficient of the dye solutions as this interaction always increases the amount of ^+H ions in the aqueous solution of the dye, which will consequently increase the acidity of the samples [1].

3. RESULTS AND DISCUSSION

The exposed dye solution was found to be discolored which is an evidence of its structural changes. The discoloration of the dye showed a linear relation with respect to absorbed dose. The color of the control samples remained stable and its exposure to visible light did not cause any impact on the color of the dye.

Figure **2** elaborates the relationship between absorbed dose (D) and absorbance (A). It shows the decrease in absorbance (A) as a function of absorbed dose (D) at the primary absorption band maxima (λ_{max} =422 nm) for the sample solutions having concentration C_2=66.88µmol/L

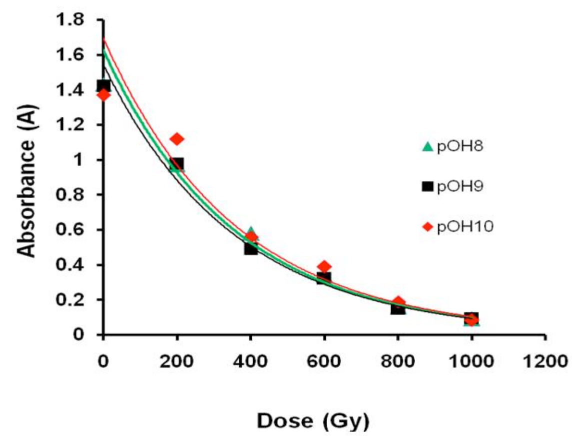

Figure 2: The exponential decrease in the absorbance (A) with respect to the absorbed dose (D).

$$A = 1.627e^{-0.00D} ; R^2 = 0.990 \quad (3.1)$$

$$A = 1.543e^{-0.00D} ; R^2 = 0.992 \quad (3.2)$$

$$A= 1.697e^{-0.00D} ; R^2 = 0.973 \quad (3.3)$$

Equations 3.1-3.3 gives the mathematical forms of the exponential behavior of dosimetric response of Sandalfix Golden Yellown CRL. Dose versus negative logarithm of absorbance (A) for the sample solutions having concentration C_1=133.75µmol/L is given in Figure **3**.

$$R^2 = 0.967 \quad (3.4)$$

$$R^2 = 0.923 \quad (3.5)$$

$$R^2 = 0.973 \quad (3.6)$$

Equations 3.4-3.6 gives the values of correlation coefficients among dose (D) and the negative logarithm of absorbance (-log A) which shows their strong relationship. The absorbance (A) of the exposed samples has decreased due to gamma ray interaction with dye solution, increasing the acidity of the samples [1]. Figure **4** explains the graphical relationship between pH and absorbance (A) of the sample solutions having concentration C_1=133.75 µmol/L.

This graph shows that in aqueous solutions, 1:1 of the H-ions to the γ-rays is found, so the acidity of the

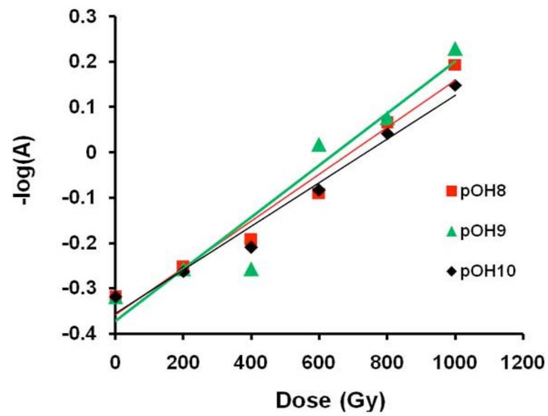

Figure 3: Radiation response function in terms of negative logarithm of absorbance (A) as a function of Dose for C_1=133.75 μmol/L.

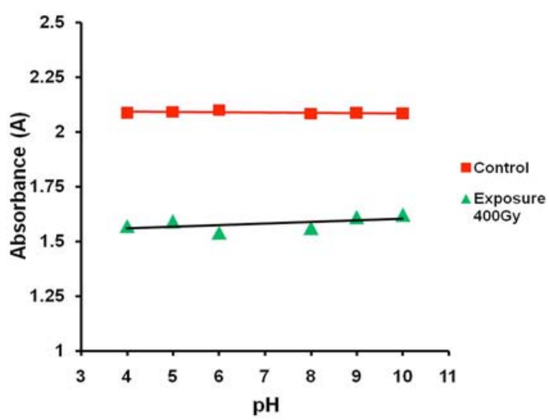

Figure 4: The graph between pH and absorbacne (A) of sample solutions treated at 400Gy.

samples has increased being a strong evidence of the gamma ray interaction with matter [1].

4. CONCLUSION

The aqueous solutions of Sandalfix Yellow CRL dye were found useful for the dosimetric calculations in the range 0-1kGy. No significant difference has been observed in the spectrophotometric readouts although the irradiation source has been replaced from Co^{60} (having dose rate 12Gy/hour) to Cs^{137} (having dose rate 660Gy/hour). The dosimetric behavior of the selected dye remained almost unchanged.

5. FUTURE RECOMMENDATIONS

For future work, one may use this dye in some other polar solvents other than the demineralized water, to check the dosimetric behavior of this dye. 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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