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# USABILITY OF AQUEOUS SOLUTIONS OF COMMERCIAL REACTIVE DYE FOR GAMMA DOSIMETRY

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## ABSTRACT

*The aqueous solutions of the Sandalfix Red C4BLN dye were used to determine the effect of γ-radiation source ($Cs^{137}$) in the range 0-1kGy. UV/VIS spectrophotometer was used to determine the absorption band maxima ($\lambda_{max}$) of the dye which was 543 nm and absorbance (A) of the sample solutions was studied at this $\lambda_{max}$ at pre and post irradiation stages. The absorbance (A) of the sample solutions was found to be decreased with increasing absorbed dose (D) showing the standard exponential decreasing pattern. The γ-irradiation caused the structural changes in the dye solution and so the discoloration of the dye was found linear with respect to absorbed dose (D).*

**Keywords:** Sandalfix Red C4BLN; dosimetry; $Cs^{137}$; gamma irradiation

## INTRODUCTION

It is an established fact that the physical and chemical changes are occurred in the exposed materials due to high energy radiations interaction with matter (Nasef et al., 1995). The procedure of determining the delivered quantity of ionizing radiations is called Radiation Dosimetry (Hussain et al., 2009, Hussain et al., 2012, 2012[a]). 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 (Massaki et al., 2007). 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 (Ahmad and Pausa, 2007; Rauf and Ashraf, 2008). Color bleaching and irradiation doses show, most of the times, a proportional behavior (Hussain et al., 2012).

The verification of the Sandalfix Red C4BLN to be used in dosimetric calculations within the γ-radiation dose range 0-1kGy delivered by $Co^{60}$ was already reported (Hussain et al., 2009) as the said dye obeyed Beer's Law. In order to observe the change in the $\lambda_{max}$ 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 i.e., 0-1kGy. The application range depends on the concentration of the dye and the nature of the solvents used (Emi et al., 2007). 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 (Khan et al., 2002). 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

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the dye depends linearly upon the amount of dose absorbed (Parwate et al., 2007; Ebraheem et al., 2003; Bagyo et al., 1996).

## EXPERIMENTAL

### Materials and methods

#### *Sample preparation*

Sandalfix Red C4BLN (CI: 195A, MW=1033.5 amu), available with the *Sandal Dyestuff Industries, Pvt. Ltd. Faisalabad, Pakistan* was used and the chemical structure of the dye is shown on the figure **1**.

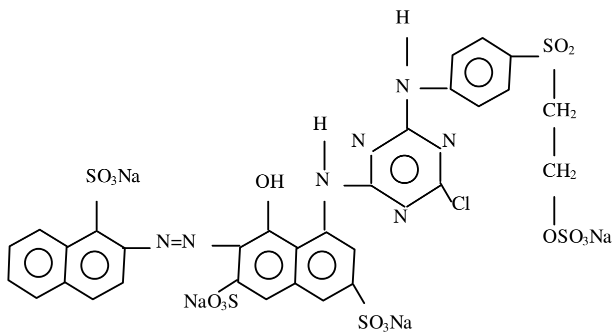


Figure 1: Structure diagram of Sandalfix Red C4BLN

The electrical balance Mettler H35AR (USA) was used to weigh the dye and so 0.125g 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 $C_1$=129.2µmol/L, $C_2$=64.6µmol/L and $C_3$=32.3µmol/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 for those of alkaline solutions; it was set as 8, 9 and 10 respectively. Moreover, the solutions of pH 7 termed as "Control solutions", remained 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°C). The dye has absorption band maxima i.e., $\lambda_{max}$=543nm determined by T80 UV/VIS spectrophotometer. The absorbance (A) of all the samples was measured at this value of $\lambda_{max}$.

#### *Sample Irradiation*

$Cs^{137}$ 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 (Hussain et al., 2012[a]; Khan et al., 2002).

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***Response Curves***

The response curves were plotted for pH 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 (-logA) and dose (D) (Nasef et al., 1995). The effect of gamma ray interaction with dye was 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 consequently increase the acidity of the samples (Nasef et al., 1995).

## 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.

The relationship between Absorbed Dose (D) and Absorbance (A) is shown in figure 2, which showed the decrease in Absorbance (A) at the $\lambda_{max}$ of dye solutions as a function of the absorbed dose (D).

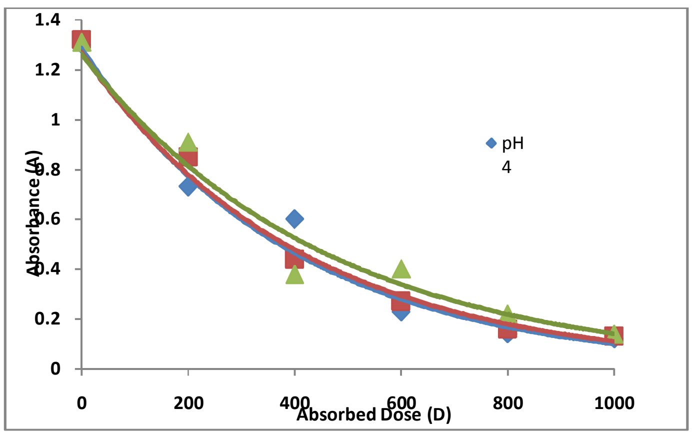


Fig. 2: The exponential decrease in the absorbance (A) with respect to the absorbed dose (D)

$$A_4 = 1.28e^{-0.003D}; \quad R^2 = 0.964 \quad (3.1)$$

$$A_5 = 1.27e^{-0.002D}; \quad R^2 = 0.985 \quad (3.2)$$

$$A_6 = 1.26e^{-0.002x}; \quad R^2 = 0.958 \quad (3.3)$$

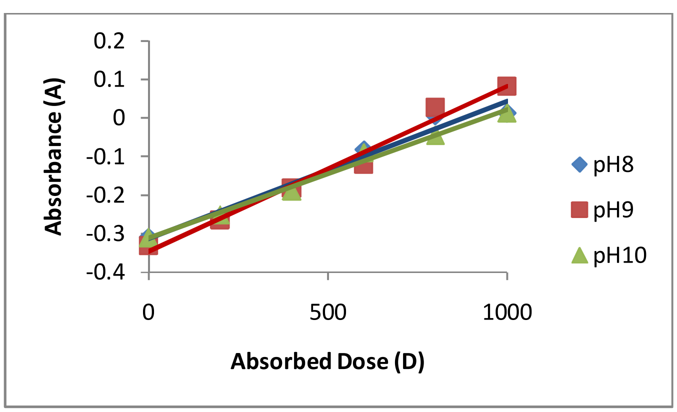


Fig. 3: Radiation response function *–logA* and absorbed Dose (*D*)

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Equations 3.1-3.3, give the regression models and the values of correlation coefficients ($R^2$) of the exponential behavior of dosimetric response of Sandalfix Red C4BLN versus the absorbed dose (D). Dose versus negative logarithm of Absorbance (-logA) is given in figure 3.

$$-\log A_8 = 0.0004D - 0.314; \quad R^2=0.971 \qquad (3.4)$$

$$-\log A_9 = 0.0004D - 0.346; \quad R^2=0.983 \qquad (3.5)$$

$$-\log A_{10} = 0.0003D - 0.311; \quad R^2=0.990 \qquad (3.6)$$

Equations 3.4-3.6, give the regression models and the values of correlation coefficients ($R^2$) among dose (D) and the negative logarithm of absorbance (-logA) 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 (Nasef et al., 1995). pH versus Absorbance (A) is given in figure 4.

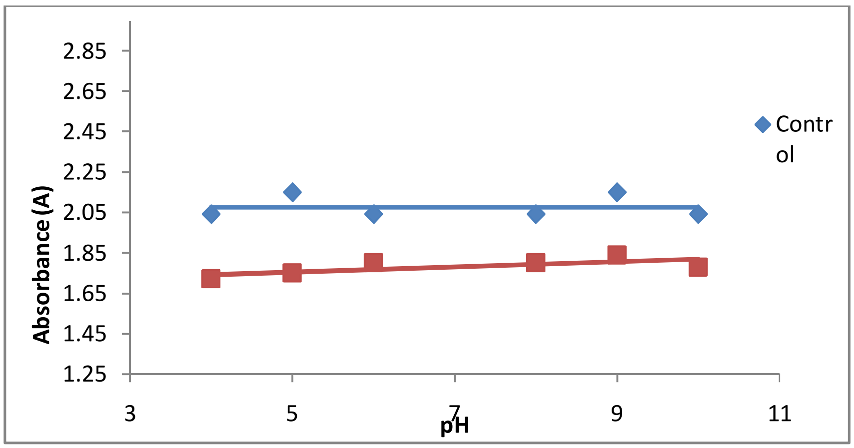


Fig. 4: The variation in absorbacne (A) of sample solutions with respect to pH

This graph shows that in aqueous solutions, 1:1 of the H-ions to the γ-rays is found, so the acidity of the samples has increased being a strong evidence of the gamma ray interaction with matter (Hussain et al., 2012[a]).

## CONCLUSION

The aqueous solutions of Sandalfix Red C4BLN 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.

## 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 dye.

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