A Study of Percentage Decoloration of Aqueous Solutions of a Synthetic Dye for Gamma Dosimetry

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Abstract— In this study, radiolysis induced decoloration (in terms of %decoloration) of aqueous solutions of Sandalfix Orange C2RL (SO) dye was investigated. A UV/VIS spectrophotometer was used for spectrophotometric analysis of sample solutions. Sample solutions were irradiated by using Cs^{137} gamma source within 0.1-100 kGy dose range. The decoloration was resulted by interaction of gamma radiation with the chromophoric group present in dye molecule and reactions of dye molecule with the primary species produced by water radiolysis. The %decoloration (%Đ) was found to be increased with respect to absorbed dose (D) within selected dose range.

Index Terms— Color, Decoloration, Dosimetry, Dye, Radiolysis, Sandalfix Orange, SO

1 Introduction

Ionizing radiations (IRs) have enough energy that can change the properties of chemical dosimeters due to which they respond logarithmically, linearly or exponentially etc. upon irradiation under suitable conditions. Synthetic dyes are being used to impart color and have been used for dosimetric purposes in aqueous solutions [1], [2], [3], [4], [5], [6], [7], [8], [9]. Dyes are characterized on the basis of their structure, color and method of application in color index; and can be categorized as nitro dyes, anthroqinone dyes, arylmethane dyes, acridine dyes, quinine-amine dyes, azo dyes and xanthene dyes [10].

In aqueous solutions, IRs can produce the hydrated electron, H_2O_2, H_2, +H and •OH radical etc. and this formation depends upon the linear energy transfer value of radiation [11]. The γ-ray interaction with the dye solutions caused the enhancement of number of +H ions in the solutions; consequently, increases the acidity of the sample solutions.

Dyes are colored in nature and earlier studies showed that irradiation can change their color providing an evidence of IR interaction with dye molecule. IRs may be promising for the treatment of textile dye waste discharge because the effect of IRs can be strengthened in aqueous solution; the degradation efficiency of dye molecule enhanced by the primary products formed from the radiolysis of water [12]. Researchers have used different colors i.e., sandalfix red C4BLN [13], sandalfix golden yellow CRL [9], methyl blue [14], methyl orange [15], direct yellow 12 [11] and alizarin yellow GG [16] etc. for dosimetric purposes and reported in last decade.

Decoloration and degradation of dyes in aqueous solutions can be achieved by gamma irradiation [17]; the addition of H_2O_2 can effectively breaks dye molecule resulting in higher color removal efficiency [18]. Radiolysis induced decoloration of the aqueous solutions of dye can be used in radiation processing for dose measurement. Preliminary studies for the dosimetric response of Sandalfix Orange C2RL (SO) dye has already reported [1], [2]. The *SO* dye is cost effective and easily available in market.

The present work deals with the study of *decoloration* (in terms of %decoloration) of SO dye in aqueous solutions within *0.1-100 kGy* dose range.

2 Experimental

SO was collected from Sandal Dyestuff Industries Pvt. Ltd. Faisalabad, Pakistan, and was used without further purification. Figure 1 showed the molecular structure of *SO* dye. For the preparation of the aqueous solutions of the selected dye, 0.5-gram (weighted by Mettler H35AR (USA) balance) of *SO* was dissolved in one liter of deionized water collected from Pakistan scientific traders, Faisalabad, Pakistan. The pH of sample solutions was measured by pH meter (Hanna HI 83141) and controlled by using one molar solution of NaOH and HCl, respectively. Sample solutions having pH 2, 3, 4, 5 and 6 were prepared and all the solutions were kept in black box to avoid the unnecessary absorbance of light. A UV-VIS spectrophotometer (Lambda 25 1.27, PerkinElmer, USA) was used for the determination of absorption peak (λ_{max}); absorbance (A) of all the solutions was calculated at this λ_{max}.

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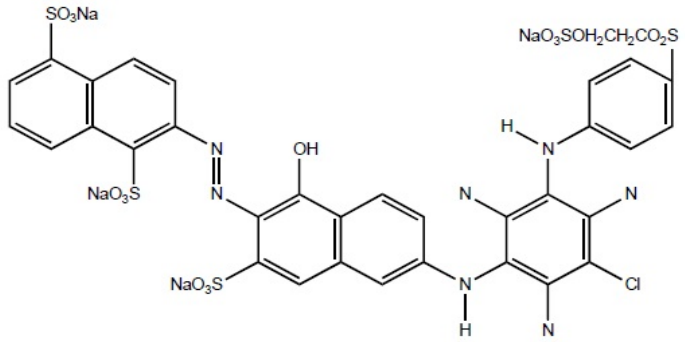

Fig. 1: Molecular structure of *SO* dye

Cuvettes (path length of 1 cm) were used to keep the solutions in the object beam.

Cs^{137} gamma radiation source (having dose rate 660 Gy/h) available at Nuclear Institute of Agriculture and Biology (NIAB), Faisalabad, Pakistan, was used for irradiation of the sample solutions. Glass ampoules (internal diameter of 1.03cm) were used to keep the solutions in the γ-irradiator for predetermined time interval. Irradiation of the samples was categorized in three phases i.e., *low* (0.1-1 kGy), *intermediate* (1-10 kGy) and *high* (10-100 kGy) dosimetry ranges, respectively.

3 Results and Discussion

Azo dyes are chemical compounds having N=N group; due to the delocalization of electrons through the N=N group, these compounds have intense colors depending on the chromophore and extent of conjugation. Most probably, the first act of radiation is the destruction of this double bond. The radiolysis of water caused the formation of primary intermediates (i.e., •OH, •H and e_{aq}^- etc.) that react with the dye molecule and take part in the decomposition of dye [10]. During the reaction between these intermediates and the azo dyes, hydrazyl type radicals are formed in first step by adding the radical to N=N group. The combination of these radicals caused the saturation of the N=N and decoloration of the solution; the disproportion may restore the N=N and also color of the solution [19]. The decoloration of water soluble dyes primarily resulted from the reactions of dye molecules with the •OH radicals produced by water radiolysis [20]. The addition of •OH to N=N caused the formation of transient with maximum wavelength in visible range [21] i.e., 430 nm for *SO*.

Irradiation caused the removal of this chromophoric group and hence decrease in colour intensities was observed. The *%decoloration (%Đ)* can be calculated in terms of absorbance (A) of the sample solutions at pre and post irradiations stages as given in equations 1 [16].

$$\%Đ = [(A_\circ - A_i)/ A_\circ] \times 100 \quad (1)$$

Where, %Đ, $A_\circ$ and A_i show the percentage decoloration, absorbance of the pre-irradiated and absorbance of post-irradiated sample solutions, respectively.

Fig. 2, 3 and 4 demonstrated the response of %Đ for the sample solutions of *SO* dye having pH 2, 3, 4, 5 and 6 within low, intermediate and high dosimetry range, respectively. The %Đ was found to be increased with respect to absorbed dose (D) and followed an exponential function for low dosimetry range; logarithmic increase was observed for both intermediate and high dosimetry ranges.

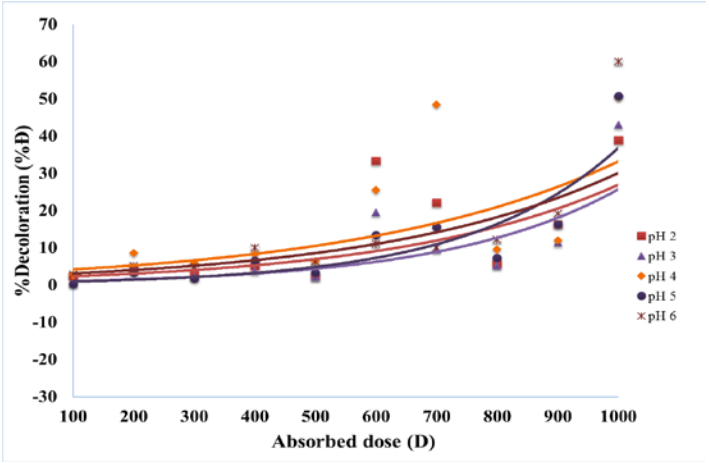

Fig. 2: Response of %Đ within low dosimetry range

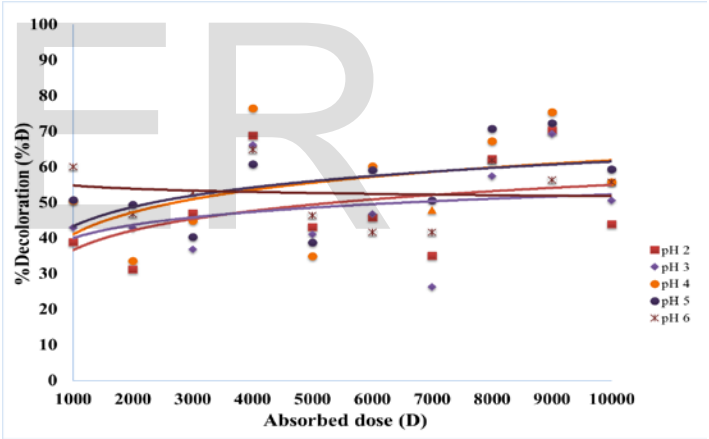

Fig. 3: Response of %Đ within intermediate dosimetry range

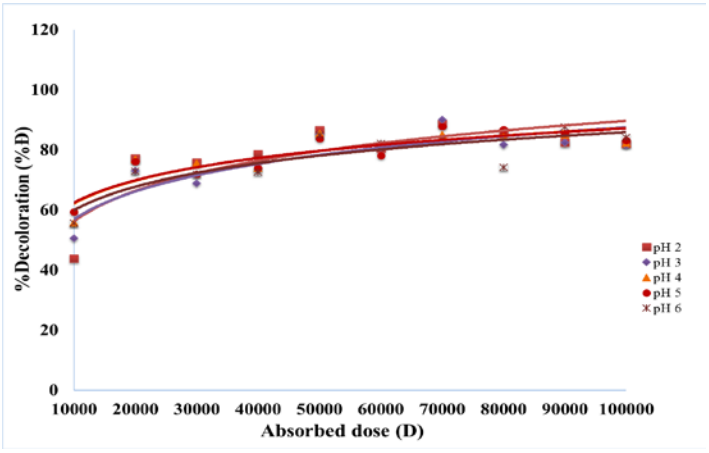

Fig. 4: Response of %Đ within high dosimetry range

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4 CONCLUSION

Decoloration of sample solutions of *SO* dye was resulted from breakage of chromophoric group upon irradiation and the reactions of dye molecules with the primary species produced by water radiolysis. The decoloration of sample solutions of *SO* was increased with respect to absorbed dose (D). The response of %decoloration (%Đ) followed an exponentially increasing function within low dosimetry (0.1-1 kGy) while logarithmic increase was observed for both intermediate (1-10 kGy) and high (10-100 kGy) dosimetry ranges. The experimental results showed that about 90% dye was decolorized within the selected dose range.

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REFERENCES

[1] M. K. Hayat, Ramiza, T. Hussain, A. H. Saeed, Inam-ul-Haq and N. Akhtar, "Effect of Gamma Radiation on the Mean Absorbance of a Synthetic Dye in Aqueous Solutions and Its Possible Use in Gamma Dosimetry", *J. Chem. Biol. Phys. Sci.*, vol. 7, no. 1, pp. 56-61, Nov. 2016.

[2] M. K. Hayat, Ramiza, T. Hussain, A. H. Saeed, Inam-ul-Haq and N. Akhtar, "Preliminary Studies for Dosimetric Response of a Synthetic Dye for Gamma Dosimetry", *J. Basic & Appl Sci.*, vol. 12, pp. 406-410, Oct. 2016.

[3] M. Y. Hussain, Islam-ul-Din, T. Hussain, N. Akhtar, S. Ali and Inam-ul-Haq, "Response of Sandal Fix Red C4BLN Dye Solutions Using Co 60 γ - Radiation Source as Intermediate Doses", *Pak. J. Agri. Sci.*, vol. 46, no. 3, pp. 224-227, Sep. 2009.

[4] M. Y. Hussain, N. A. Shad, N. Akhtar, S. Ali and T. Hussain, "Commercial SFG Yellow CRL Dye Aqueous Solutions for Gamma Dosimetry", *Pak. J. Agri. Sci.*, vol. 46, no. 1, pp. 78-81, 2009.

[5] T. Hussain, M. A. K. Shahid, M. Shahbaz, Inam-ul-Haq and H. Farooq, "Gamma Radiation Effect on Commercial Reactive Dye in the Range 0-100KGy Using the Idea of the De-Coloration Factor and Extinction Coefficient", *J. Basic & Appl. Sci.*, vol. 30, pp. 581-584, 2012.

[6] T. Hussain, M. Shahbaz, Inam-ul-Haq and H. Farooq, "Radiolytic Reduction of Aqueous Solutions of a Commercial Reactive Dye in the Range 0-100KGY by CO 60 Gamma Radiation Source", *J. Basic & Appl Sci.*, vol. 8, pp. 280-285, 2012.

[7] T. Hussain, M. Y. Hussain, M. Shahbaz, Inam-ul-Haq, H. Farooq and S. Ali, "Radiolysis of Commercial Dyes in Aqueous Solutions to Produce Dosimeters for Gamma Dosimetry", *J. Basic &Appl Sci.*, vol. 8, pp. 315-318, 2012.

[8] T. Hussain, M. Shahbaz, Inam-ul-haq, H. Farooq, N. Amin and Y. Jamil, "Dosimetric Characteristics of Aqueous Solutions of Sandalfix Red Dye for Gamma Dosimetry", *J. Basic & Appl Sci.*, vol. 8, pp. 437-443, Sep. 2012.

[9] M. Y. Hussain, T. Hussain, I. Toqeer, N. Akhtar, Inam-ul-Haq and H. Farooq, "Gamma Dosimetric Response of Sandalfix Golden Yellow CRL Dye Solutions for Gamma Dosimetry Using Cs137 in the Range 0-1KGy", *J. Basic & Appl Sci.*, vol. 8, pp. 482-484, Nov. 2012.

[10] M. A. Rauf and S. S. Ashraf, "Radiation Induced Degradation of Dyes — An Overview", *J. Hazard Mat.*, vol. 166, pp. 6-16, 2009.

[11] J. Batool, S. A. Shahid, Ramiza, N. Akhtar, A. Naz, M. Yaseen, I. Ullah, M. Nadeem and I. Shakir, "A Study on Dosimetric Characterization of Direct Yellow 12 Dye at High Radiation", *Bull. Korean Chem. Soc.*, vol. 33, no. 7, pp. 2265-2268, Apr. 2012.

[12] N. Getoff and W. Lutz, "Radiation Induced Decomposition of Hydrocarbons in Water Resources", *Radiat. Phys. Chem.*, vol. 25, no. 1–3, pp. 21, 1985.

[13] F. Akhtar, T. Hussain, M. Shahbaz, Inam-ul-Haq, I. Toqeer and H. Farooq, "Usability of Aqueous Solutions of Commercial Reactive Dye for Gamma Dosimetry", *Natural and Appl. Sci.*, vol. 5, no. 1, pp. 32, Jan. 2014.

[14] S. Akhtar, T. Hussain, A. Shahzad and Qamar-ul-Islam, "The Feasibility of Reactive Dye in PVA Films as High Dosimeter", *J. Basic App. Sci.*, vol. 9, pp. 420-423, 2013.

[15] S. Akhtar, T. Hussain, A. Shahzad, Qamar-ul-Islam, M. Y. Hussain and N. Akhtar, "Radiation Induced Decoloration of Reactive Dye in PVA Films for Film Dosimetry", *J. Basic & Appl. Sci.*, vol. 9, pp. 416-419, May. 2013.

[16] W. Sun, L. Chen, J. Tian, J. Wang and S. He, "Degradation of a Monoazo Dye Alizarin Yellow GG in Aqueous Solutions by Gamma Irradiation: Decolorization and Biodegradability Enhancement", *Radiat. Phys. Chem.*, vol. 83, pp. 86-89, 2013.

[17] D. Solpan and O. Guven, "Decoloration and Degradation of Some Textile Dyes by Gamma Irradiation", *Radiat. Phys. Chem.*, vol. 65, pp. 549-558, 2002.

[18] M. A. R. Bhuiyan, A. Shaid, M. A. Hossain and M. A. Khan, "Decolorization and Degradation of Textile Wastewater by Gamma Irradiation in Presence of H2O2", *Life Sci. J.*, vol. 13, no. 10, pp. 56-62, Oct. 2016.

[19] D. Şolpan, O. Güven, E. Takács, L. Wojnárovits and K. Dajka, "High-energy Irradiation Treatment of Aqueous Solutions of Azo Dyes: Steady-State Gamma Radiolysis Experiments", *Radiat. Phys. Chem.*, vol. 67, pp. 531-534, 2003.

[20] D. Solpan and M. Torun, "Effect of Gamma-Irradiation on Aqueous Solutions of Apollofix Dyes", *Nukleonika*, vol. 52, pp. 109-113, 2007.

[21] L. Wojnárovits and E. Takács, "Irradiation Treatment of Azo Dye Containing Wastewater: An Overview", *Radiat. Phys. Chem.*, vol. 77, no.3, pp. 225-244, 2008.

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