Dosimetry Characterization of Unknown Dye Polyvinyl Alcohol Films

Muhammad Attique Khan Shahid[a,*], Noureen Kousar[a], Naseem Akhtar[b], Taqmeem Hussain[a], Mariam Saeed Awan[b], Arfa Mubashir[b], Bushra Bashir[b] and Asif Javed[b]

[a]*Department of Physics,GC University, Faisalabad, Pakistan*

[b]*Nuclear Institute for Agriculture and Biology, Faisalabad, Pakistan*

Abstract: In the present study chemical dosimeters having aqueous solutions of crystal violet commercial dye were irradiated by Co^{60} γ source in the range (0-120)KGy. The standard aqueous solutions were scanned by UV/VIS spectrophotometer for the determination of maximum wave length (λ_{max}) which was found to be 591nm at this value maximum absorbance was found to be 3.5; it was also observed that with increase in dose, absorbance decreases correspondingly. At this value, the absorbance (A) of irradiated samples was measured in UV region. The plot between concentration C and A gave approximate linear relationship and hence verified Beer's Law which proved that these dye solutions can satisfactorily be used as the dye dosimeters in 0-120kGy gamma dose range.

Keywords: Aqueous solutions, the crystal violet dye, dosimetry, gamma irradiation, Optical density (OD), decolouration.

1. INTRODUCTION

Radiation (may be electromagnetic, light photons or ionizing radiations comprised of γ-photons, α or β-particles) is emission and propagation of energy from one point to another from a source to sink. The ionizing radiations can cause biological, chemical as well as physical changes in the exposed matter. So Co^{60} γ-radiation source caused chemical changes in the aqueous solutions of crystal violet commercial dye in the form of increase in the acidity of the sample solutions (a definite clue of gamma interaction with water). The present study dealt to find a new dye dosimeter of its type. Radiation doses are generally measurable with linear response, over absorbed dose ranges between 1 and 10^4Gy, depending on the initial dye concentration, the pH and the presence of additives as alcohols, buffers and inorganic salts [1-14]. This dye is relatively a cheap dye. The aim of the present work was to explore that the synthetic commercial dye can be used as a dosimeter. It is known that commercial dyes contain pigmentations (colouring substances) which are used to impart colour to the fibres. However, these dyes also have other uses like as chemical dosimeters for high gamma radiation doses [15]. The overall objective of this work was to check for this commercial dye to respond to Gamma radiation like as a dosimeter. Furthermore, the other parameters studied were the effect of dye concentration on the gamma response and the verification of Beer's law in order to find the suitability of this commercially available dye to be used for dosimetric studies in 0-120kGy dose range.

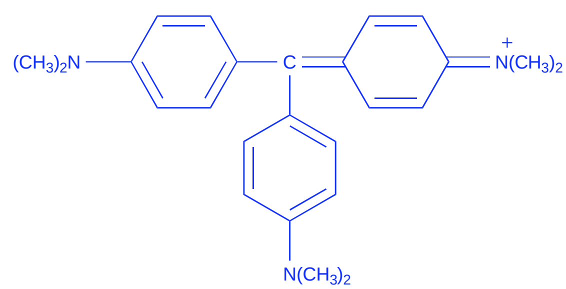

Figure 1: The structure of crystal violet.

2. MATERIALS AND METHODS

The stock solution of crystal violet ($C_{25}H_{30}N_3Cl$) dye was prepared by preparing the dye concentrations in de-mineralized water that was collected from Steam Power Station, Faisalabad and had electrical conductivity less than 1μSiemens/cm. The pH of this solution was found to be nearly 7.0. The dye was readily dissolved in water at room temperature because of its high solubility. From the stock solution, different concentrations of the dye such as C_1=0.019/L, C_2=0.029g/L and C_3=0.039g/L were prepared at different pH values. In dosimetric studies, those dye dosimeters are considered to be satisfactory which show a linear relationship between the concentrations (C) of the dye in the solutions and absorbance (A) measured at the primary absorption peak maxima that is actually verification of Beer's Law [1-14]. For irradiation, the dye solutions were placed in 5 ml glass ampoules having internal diameter 1.03 cm and

*Address corresponding to this author at the Department of Physics,GC University, Faisalabad, Pakistan; Tel: 0302-6062879;
E-mail: profkhan786@yahoo.com

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

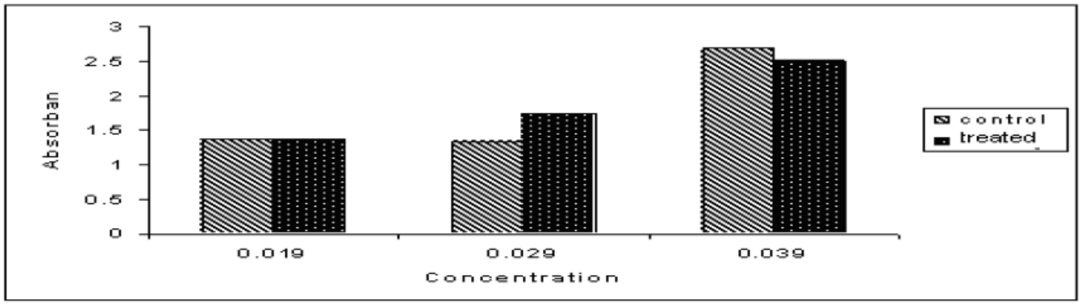

Figure 2: Relationship between absorbance and concentration after irradiation of samples.

thickness 0.18 cm with fit in ground stoppers. Co^{60} gamma radiation source (Mark IV Irradiator) available at Nuclear Institute of Agriculture and Biology (NIAB), Faisalabad and having dose rate of 12Gy/h was used to irradiate the samples. All the samples were irradiated at room temperature by placing them inside the irradiation chamber at fixed positions in the gamma flux with the help of a fixed stand. The samples were irradiated according to pre-selected doses, i.e.40kGy, 60kGy, 80kGy, 100kGy and 120kGY. The samples were scanned for optical wavelength (λ_{max}) and the absorbance (A) measured by double beam T80 UV/VIS spectrophotometer having band pass setting of 1mm. The dye has λ_{max}=591nm determined by T80 UV/VIS spectrophotometer. Beer's Law was verified by plotting the absorbance (A) versus concentration (C) as shown in Figure **2**.

3. RESULTS AND DISCUSSION

The optical wavelength (λ_{max}) of the samples was measured with a double beam spectrophotometer using a band pass setting of 1mm. The absorption spectra of un-irradiated and irradiated dye solutions were recorded in the range 190-700nm. The absorption spectra of crystal violet were recorded for the range of absorbed dose (0-120kGy) of gamma rays is shown in Figure **3**. [16] prepared crystal violet doped polyvinyl alcohol blended with chloral hydrate and methyl green doped polyvinyl butyric blended with chloral hydrate films by solvent casting method. The blends were irradiated with γ radiation at doses of up to 110kGy. The CV doped PVNCH blends change colour from violet to blue at high dose (40 to 60kGy) before bleaching at higher doses due to the formation of acid by radiation induced decolourisation of CH. The absorption spectra was measured and analysis spectrometrically. The absorbance at the absorption band at 590 nm, the characteristic of violet colour, decreases with increasing dose. In conclusion, was shown radiation effects by y-rays on CV doped PVAICH and MeG doped PVB/CH blend films, which affected the dosimetric and optical properties, could be evaluated with suitable reproducibility by measuring the optical stimulation [17]. In our study, the spectra of control and irradiated samples also showed absorption peak at 591nm. Thus, wavelengths of maximum absorption should be the suitable wavelengths for the

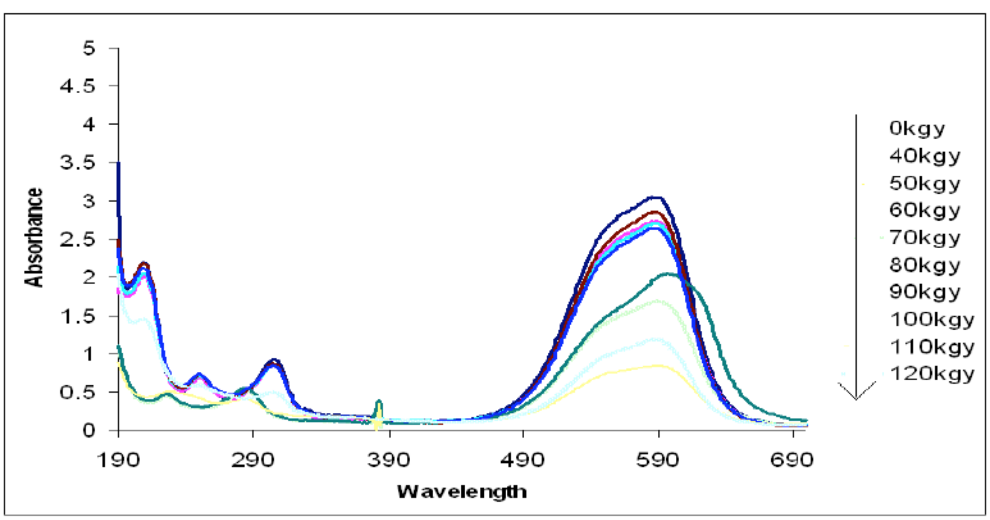

Figure 3: Absorbance spectra of CV-PVA films un-irradiated and irradiated to dissimilar absorbed dose.

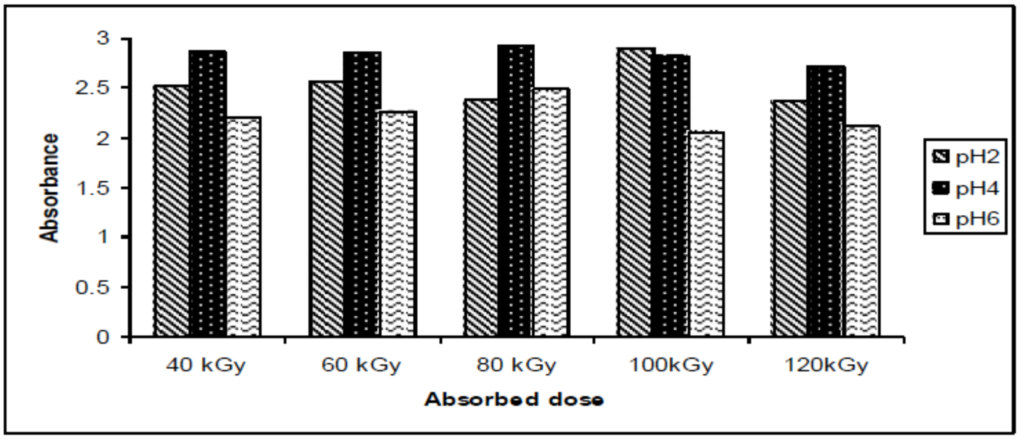

Figure 4: Relationship between dose and absorbance of crystal violet samples.

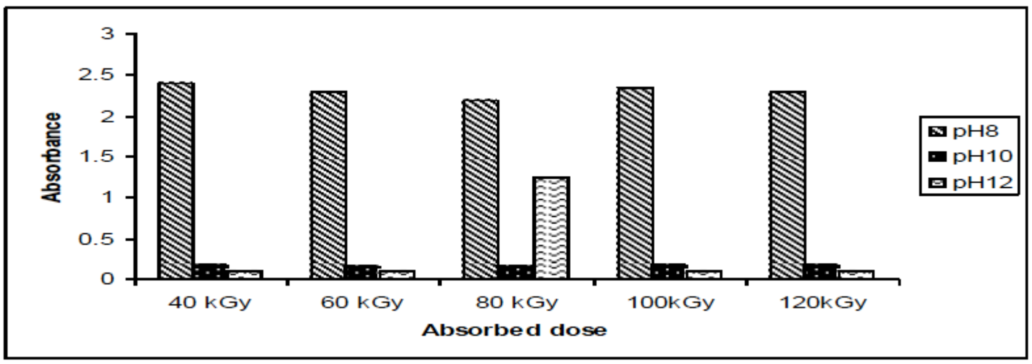

Figure 5: Relationship between absorbed dose and absorbance of crystal violet samples.

characterization of this dye dosimeter. Further, these spectra also showed about 591nm wavelength, the absorbance decreased with the increase in the irradiation dose which confirmed the occurrence of bleaching of dye about both the regions of maximum wavelengths as the absorbed dose is increased. Hence, 591nm was chosen as the λmax (the absorption peak).

Figure **4** shows the absorption spectra of the control and treated aqueous dye solutions. The decrease in the absorbance (A) as a function of absorbed dose (D) for basic samples is shown in the Figure **5**. It is obvious from the figure that the radiation induced loss in the dye concentration with dose as a linear fit on a plot.

The gamma radiation response for the aqueous solutions of the crystal violet in terms of absorbance as a function of the absorbed dose for basic samples is shown in Figure **5**. The effect of pH on the response of aqueous solutions of the dye was also studied. The pH of the samples was measured at pre- and post-

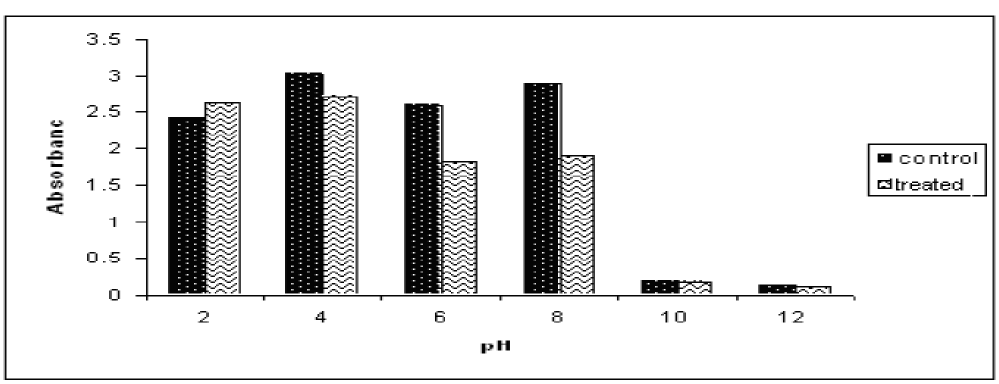

Figure 6: Effect of pH on the absorbance of sample solutions.

irradiation. The plot between the absorbance (A) [18, 25] of the samples versus their pH is shown in Figure **6**. Figure **7** Showed how colour of CV-PVA film changes from dark violet to light violet after irradiation with Gamma rays.

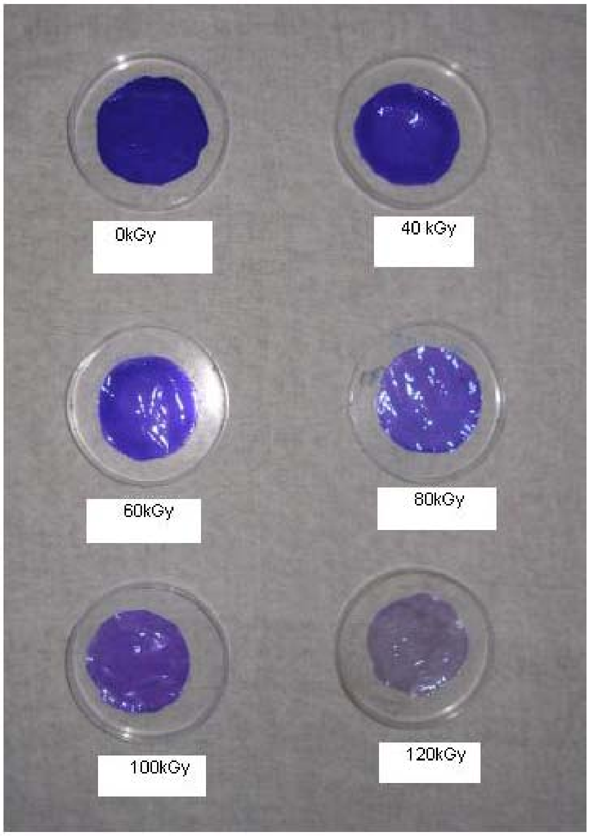

Figure 7: Colour of CV-PVA film changes from dark violet to light violet after irradiation with Gamma ray.

4. CONCLUSION

The decolouration and degradation of crystal violet commercial dye in aqueous solution by gamma radiation has been demonstrated. The linear relationship found between absorbance and concentration verified Beer's Law which confirmed that crystal violet commercial dye can be used as a dosimeter over a small range of gamma dose ranging from 0–120kGy. The pH of sample solutions being a great factor to affect the response of the solutions should also be carefully handled. However, additional studies are still required to increase the radiation doses beyond 120kGy, to evaluate the dose rate and energy dependency.

ACKNOWLEDGEMENT

Special thanks to Director, NIAB Faisalabad for providing the irradiation and laboratory facilities. Moreover, the authors are thankful to the faculty and Chairman along with Dr. Shoukat Ali, Department of Chemistry and Biochemistry, UAF, for the dye as well as for the scientific and technical help provided during the course of this experiment.

FUTURE PROSPECTS

Dye dosimetry is an active area of research now a day, if it should be checked that the whole process of extraction and dying must be not only ecologically safe but also extremely less damaging for human health. No doubt there is a lot of scope of dye dosimetry for obtaining multi colour shades as per requirement of the textile and painting industry, using different doses and eco-friendly textile industrial procedures with proper dose delivery check up, enhancement of shelf life, sterilization and pasteurization, waste management without opening boxes, drums and sacs using colour change technique.

The above said future objectives will only be achieved by getting proper knowledge of radiation protection and safety, documentation and dose assessment techniques.

REFERENCES

[1] Nasef B, El Assy, Yun-Dong C, Walker ML, Sheikhly MA, Mclaughlin WL. Anionic triphenylmethane dye solutions for low-dose food irradiation dosimetry. Radiat Phys Chem 1995; 46: 1189-97. http://dx.doi.org/10.1016/0969-806X(95)00353-Y

[2] Baker C, Sharifeh AD, Kudrimoti M, Shahid BA, Ali SM. Dosimetric evaluation of a newly designed low dose rate brachytherapy applicator for treatment of cervical cancer with extension into the lower vagina. J Appl Clin Med Phys 2007; 8(2): 37-46.

[3] Barakat MF, Salamawy KE, Banna ME, Abdel-Hamid M, Abdel-Rehim AT. Radiation effects on some dyes in non-aqueous solvents and in some polymeric films. Radiat Phys Chem 200; 61: 129-36.

[4] Buenfil AE, Ruiz-Trejo C, Gamboa-deBuen I, *et al*. Response of radiochromic dye films to low energy heavy charged particles. Nuc Instrum Meth Phys Res B 2002; 197: 317-22. http://dx.doi.org/10.1016/S0168-583X(02)01488-X

[5] Farah K, Kuntz F, Kadri O, Ghedira L. Investigation of the effect of some irradiation parameters on the response of various types of dosimeters to electron irradiation. Radiat Phys Chem 2004; 71: 337-41. http://dx.doi.org/10.1016/j.radphyschem.2004.05.041

[6] Ebraheem S, Beshir WB, Eid S, Sobhy R, Kov AA. Spectrophotometric readout for an alanine dosimeter for food irradiation applications. Radiat Phys Chem 2003; 67: 569-73. http://dx.doi.org/10.1016/S0969-806X(03)00107-5

[7] Hussain MY, Shad NA, Nasim-Akhtar, Ali S, Hussain T, Inam-ul-Haq. Commercial SFG Yellow CRL dye aqueous solutions for gamma dosimetry. Pak J Agri Sci 2009; 46(1): 78-81.

[8] Hussain MY, Islam-ud-Din, Hussain T, Nasim-Akhtar, Ali S, Inam-ul-Haq. Response of Sandal Fix Red C4BLN dye

solutions using Co^{60} γ-Radiation source at intermediate doses. Pak J Agri Sci 2009; 46(3): 224-27.

[9] Hussain T. Response of SF Red C4BLN dye using Co^{60} γ-radiation source at intermediate doses. M. Sc. Thesis. Dept. Phys Uni Agri Faisalabad Pakistan 2008.

[10] Rauf MA, Ashraf SS. Radiation induced degradation of dyes-An overview. J Hazard Mater 2008, HAZMAT-9131: 1-11.

[11] Galante AMS, Rzyski BM, Campos LL, Villavicencio AL. The response of potassium nitrate for high-dose radiation dosimetry. Radiat Phys Chem 2002; 63(3): 719-72. http://dx.doi.org/10.1016/S0969-806X(01)00605-3

[12] Hasan MK, Mohammad A, Zahid SC. Dosimetric characterisation of aqueous solution of brilliant green for low-dose food irradiation dosimetry. Radiat Phys Chem 2002; 63: 713-17. http://dx.doi.org/10.1016/S0969-806X(01)00640-5

[13] Kattan M, Daher Y, Alkassiri H. A high-dose dosimeter-based polyvinyl chloride dyed with malachite green. Radiat Phys Chem 2007; 76(7): 1195-99. http://dx.doi.org/10.1016/j.radphyschem.2006.12.004

[14] Khan HM, Anwer M, Chaudhry ZS. Dosimetric characterisation of aqueous solution of brilliant green for low-dose food irradiation dosimetry. Radiat Phys Chem 2002; 63: 713-17. http://dx.doi.org/10.1016/S0969-806X(01)00640-5

[15] Khan HM, Anwer M, Chaudhry ZS. Dosimetric characterisation of aqueous solution of brilliant green for low-dose food irradiation dosimetry. J Radiat Phys Chem 2002; 63: 713-17. http://dx.doi.org/10.1016/S0969-806X(01)00640-5

[16] Baha A. Effect of Radiation on Dosimetric and Optical Properties of Dyed Pva/Ch and Dyed Pvb/Ch Blends. Masters thesis, University Putra Malaysia 2005.

[17] El-Assy NB, El-Wakeel ES, Fattah AA. The degradation of triazo dye chlorantine fast green BLL in aqueous solution by gamma radiation–III. Int J Radiat Appl Instrum A 1991; 42: 89-96. http://dx.doi.org/10.1016/0883-2889(91)90129-O

[18] Emi RG, Andras K, Fletcher JJ. Dosimetry characterization of tetrazolium violet polyvinylalcohol films. Radiat Phys Chem 2007; 76: 1519-22. http://dx.doi.org/10.1016/j.radphyschem.2007.02.064

[19] John DR, John SH, Waldo W. Effects of several parameters on a thickness-independent radiochromic thin-film dosimetry system. Radiat Phys Chem 1995; 4-6: 1269-72.

[20] Anonymous. Interaction of radiation with matter. Dictionary of Military and Associated Terms. US Department of Defense 2005 [Online]. Available at http://www.thefreedictionary.com/radiation +dose+rate (Verified 2011).

[21] Anonymous. Radiation interaction with matter [Online]. Available at http://wiki.answers.com/Q/How_does_radiation_interact_with_matter (Verified 2011).

[22] Anonymous. Dye [Online]. Available at http://en.wikipedia.org/wiki/Dye (Verified 2011).

[23] Anonymous. Absorption spectrum of the dye solutions [Online]. Available at http://en.wikipedia.org/wiki/ultraviolet%e2%80%93visible_spectroscopy (Verified 2011).

[24] Anonymous. Absorption spectrum of the dye solutions [Online]. Available at http://en.wikipedia.org/wiki/ultraviolet%e2%80%93visible_spectroscopy (Verified 2011).

[25] Ahmad AL, Pausa SW. Reactive dyes decolourization from an aqueous solution by combined coagulation/micellar-enhanced ultrafiltration process. Chem Eng J 2007: 132: 257-65. http://dx.doi.org/10.1016/j.cej.2007.01.005

Received on 16-08-2012 Accepted on 14-09-2012 Published on 20-09-2012

http://dx.doi.org/10.6000/1927-5129.2012.08.02.42