

## A Study on Dosimetric Characterization of Direct Yellow 12 Dye at High Radiation $\gamma$ -Dose

Javaria Batool,\* Shaukat Ali Shahid,\* Ramiza, Nasim Akhtar,† Afshan Naz, Maria Yaseen, Inam Ullah,‡ Muhammad Nadeem,§ and Imran Shakir#

Department of Physics, University of Agriculture Faisalabad-38040, Pakistan

\*E-mail: javaria.batool@live.com (J. B.); shaukatuafpy@uaf.edu.pk (S. A. S.)

†Nuclear institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan

‡Department of Chemistry and Biochemistry, University of Agriculture Faisalabad, Pakistan

§Subsurface Technology, PETRONAS, Research Sdn.Bhd. Bangi-43300, Selangor, Malaysia

#Interdisciplinary Research Center in Biomedical Materials, COMSATS Institute of Information Technology, Lahore, Punjab Pakistan

Received January 30, 2012, Accepted April 4, 2012

Aqueous solution of oxygenated *Direct yellow 12 dye* has been evaluated spectrophotometrically as a possible gamma rays dosimeter. The neutral (pH-7), alkaline (pH-12.5) and acidic (pH-5.5) aqueous solution of the dye were prepared and exposed to various gamma doses. Absorption spectra of unirradiated and irradiated solutions were recorded at 400 nm peak. The increase in absorbance with the increase in irradiation dose was observed from 1 to 6 kGy. The stability response of the dye solution for different environmental conditions such as temperature (low & high), light and darkness were investigated during post irradiation storage for ten days. The dye solution showed high stability in darkness for the studied period. The optical density of the dye solution was found to be decreased at high temperature storage.

**Key Words :** Direct yellow 12, Spectrophotometry, Gamma ray dosimeter, Optical density

### Introduction

Quantitative study in radiation chemistry requires the knowledge of the amount of energy absorbed from ionizing radiation. Determination of the absorbed energy is carried out by a dosimeter.<sup>1</sup> The dosimeters usually comprise of the chemicals that respond linearly to radiation under prevalent conditions. Many rare-earths, alkaline earth metal compounds are conveniently used as a dosimeter, because various changes occur in thermo luminescence and other optical properties due to the reaction with ionizing radiations. A chemical dosimeter generally works due to change in chemical composition or physical property upon irradiation. Organic dyes comprising colored compounds have been investigated as potential chemical dosimeters. They have been utilized in solution form or embedded in various polymeric films. The effect of radiation on a given compound depends on the composition and the amount of energy that is transferred by radiation. The radiations in the aqueous solution cause the formation of transient species such as radicals and ions. The radiolysis of water is very well documented. It has been known that it produces  $H_2$ ,  $H_2O_2$ ,  $H^+$ ,  $OH^-$ , hydrated electron ( $e^-_{aq}$ ), hydroxyl radical ( $\cdot OH$ ) and hydrogen atom as intermediate species in varying amounts. The production of these species depends upon the linear energy transfer value of radiation.<sup>2</sup> Radiation effect in aqueous solution of some dyes has been already investigated as chemical dosimeter. The list includes congo red, coumarin, triphenyl methane dye, methyl blue, methyl red and formyl violet cyanide. These

dyes are commercially available with low cost and can be handled easily due to less dangerous effects. Spectrophotometric analysis have made these dyes a perfect choice as a radiation indicator.<sup>8</sup> In the present research work, the dosimetric properties of aqueous solution of *Direct yellow 12* has been investigated as high dose gamma ray dosimeter.

### Experimental

*Direct yellow 12 dye* was purchased from Sandal Dye Stuff Industries, Faisalabad, Pakistan and used as received without further purification. The dye solution, was prepared by dissolving 0.030 gms of the compound in 1000 mL deionized water with electrical conductivity 1  $\mu$ Siemens/cm. Low concentration of dye solution was prepared to achieve 100% degradation with irradiation dose as reported by Rauf and Ashraf, 2008. Different pH values of dye solution was achieved by using HCl and NaOH respectively. Each sample solution was saturated by passing oxygen for 45 minutes. The prepared solutions were placed into glass ampoules (1.8 cm in diameter and about 6 cm in length) and sealed. The Cs-137 gamma rays source of Nuclear Institute of Agriculture and Biology (NIAB) Faisalabad, Pakistan was used for the irradiation of sample. The dose rate was about 1 kGy/min which was determined by Fricke dosimeter.<sup>3</sup> Before and after irradiation the solutions were protected from light by wrapping the solutions with black papers. All the irradiation were carried out at ambient temperature. A single beam spectrophotometer (UV-Vis, U-2020) was used to record the

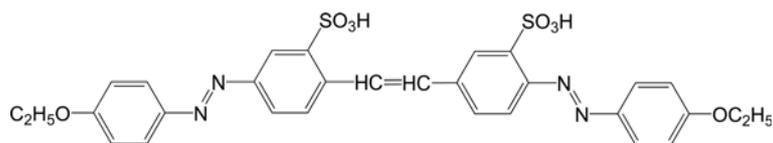


Figure 1. Chemical structure of *Direct Yellow 12 dye*.<sup>12</sup>

absorbance of samples. The absorbance of different dye solutions (acidic, basic and neutral) was measured against the appropriate blank *i.e.* deionized water.

### Results and Discussion

The chemical structure of *Direct yellow 12 dye* contain sulphonic acid at ortho positions of benzene ring. The chromophoric group N=N was also present in structure of dye as shown in Figure 1.

*Direct yellow 12 dye* solution was irradiated by gamma radiations in dose range 1-6 kGy. In general the degradation process showed reduced sensitivity at high pH values, due to acid base properties of the  $\cdot\text{OH}$  radical. In strong basic solution, the  $\cdot\text{OH}$  radicals dissociate to less reactive  $\text{O}^{\cdot-}$  radicals. Two dyes Cibacron Violet and Cibacron Golden Yellow showed decrease in degradation in pH range from 3 to 9 at high pH values.<sup>4</sup> The absorption of *Direct yellow 12 dye* solution at pH 7, 5.5 and 12.5 showed gradual increase with radiation absorbed dose as shown in Figure 2. The enhanced absorbance of dye solutions may be due to the regeneration of dye molecules in the reaction media. The increase in absorbance may also be due to the regeneration of the dye molecules by spontaneous oxidation. Dose enhancement in absorbance is consistent with the previous study of Kovacs *et al.* (1998). Dissolved oxygen or a weak oxidizing agent helps in extending the dose range of response by scavenging free-radical agents formed in the solvent during irradiation.<sup>6</sup> The correlation in radiation dose and absorbance was determined by correlation coefficient as shown in Table 1. The coefficient of determination indicated that about 88.2%, 85.5% & 93.1% change in the absorbance of acidic, basic and neutral solutions was due to radiation

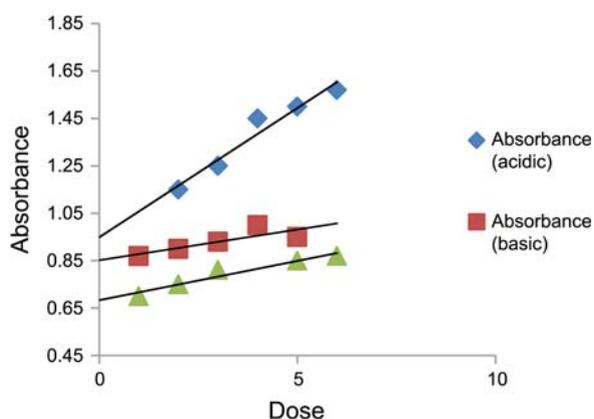


Figure 2. Response of absorbance on oxygenated direct yellow 12 dye solution at various radiation doses for three different pH values.

Table 1. Statistical relation between radiation dose and absorbance

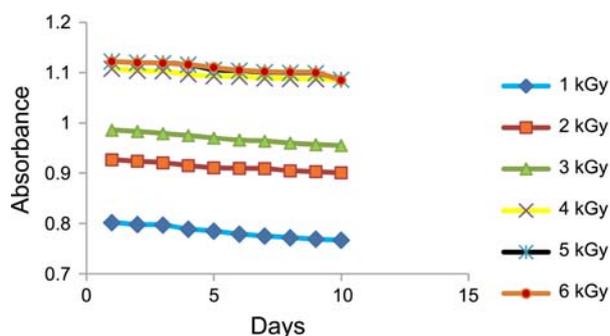
pH of solutions	Coefficient of Determination ( $R^2$ )	Sensitivity (absorbance change per 1 kGy)	Correlation Coefficient
Acidic (pH-5.5)	88.2%	0.065	0.939
Basic (pH-12.5)	85.5%	0.060	0.930
Neutral (pH-7)	93.1%	0.0749	0.974

dose and 11.8%, 14.5%, 6.9% may be due to any other factor.

**Post Irradiation Storage.** Aqueous solutions of post irradiated *Direct yellow 12 dye* for pH-7, 5.5 and 12 were stored at room temperature for ten days under different light conditions (dark and diffused sunlight) inside the laboratory. Since temperature is an important operational environmental factor which can change the response of the dosimeters.<sup>7</sup> Thus *Direct yellow 12* solution at mentioned pH were also exposed to different temperature conditions (0 and 45 °C) to check the changes in optical density of the dye solution. To observe any change in absorbance due to storage time, the absorbance were recorded after each twenty four hours for ten days at 400 nm.

**Post Irradiation Stability for Low Temperature.** To check the stability response, the *Direct yellow 12 dye* solutions (pH-5.5, pH-7 and pH-12.5) were stored for 10 days at 0 °C. The acidic oxygenated dye (*Direct yellow 12*) solutions with pH-5.5 showed decrease in absorbance for first 5 days, afterwards solution response was stable. The basic oxygenated dye solutions (pH-12.5) also showed decrease in absorbance for 5 days, after wards solution response was stable. The neutral oxygenated dye solutions at pH-7 showed decrease in absorbance for 6 days. Afterward solution response was stable, indicating that acidic and basic dye solutions were more stable than neutral solutions for post irradiation storage in low temperature for 10 days. The statistical relationship between absorbance and days of *Direct yellow 12 dye* is shown in the Table 1. The coefficient of determination ( $R^2$ ) indicates the change in absorbance with storage time for solution of different pH values. The significant change in absorbance were not observed for low temperature.

**Post Irradiation Stability for High Temperature.** The effect of high temperature (45 °C) on irradiated *Direct yellow 12 dye* solution (pH-5.5, pH-12.5 and pH-7) stored for 10 days showed rapid decrease in absorbance with time. The change in absorbance may be due to the degradation of dye solution. The fact is that the degradation scheme depends upon the relative reactivity of the different species, amount of the dose, presence of oxygen, pH and pOH of the solution



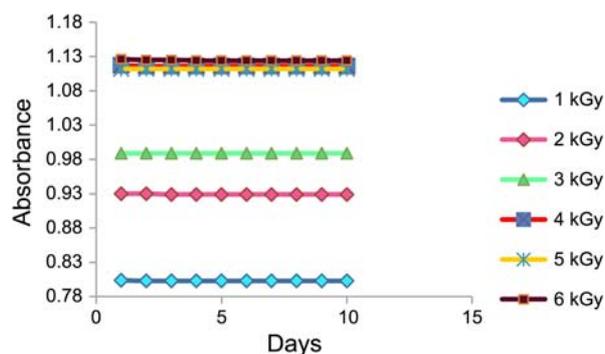
**Figure 3.** The absorbance of acidic direct yellow 12 dye solution versus storage time at 45 °C.

and temperature.<sup>2</sup> Figure 3 describes the response of absorbance with storage time of the post irradiated acidic dye solution at 45 °C. Similar behavior has been obtained for post irradiated neutral and basic dye solutions. The thermal degradation of dye solutions during the storage at high temperature showed that the irradiated dye solutions must be stored at low temperature.

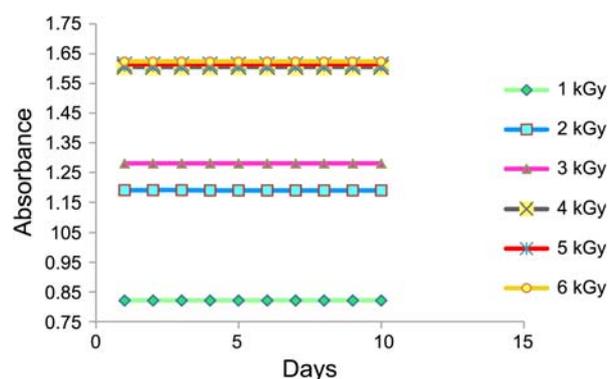
#### Post Irradiation Stability for Different Light Conditions.

To check the effect of different light conditions on the post irradiation stability of oxygenated *Direct yellow 12 dye* solution were stored for 10 days in diffused sunlight and darkness at room temperature. Irradiated oxygenated dye solutions were placed in diffused sunlight to check the response during the period of 10 days. The acidic solutions (pH-5.5) showed stability for 6 days, the stability may be the result of the very low value of the  $O^{\cdot -}$  and  $O^{\cdot 2-}$ . These radicals have very small effect on degradation.<sup>2</sup> After six days, the absorbance of solution was decreased which continued until 10 days. In acidic conditions solution combines with  $H^+$  to form  $H^{\cdot}$  species. The reducing H atoms combine with oxygen to form  $\cdot HO_2$  which plays an active role in degradation process.<sup>2</sup>

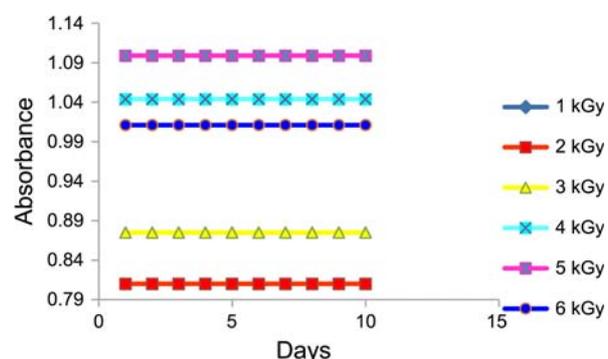
Both basic and neutral solution showed stable behavior for 1 to 7 days. Then sudden decrease was observed up to ten days indicating that neutral and basic solutions were more stable than acidic solution for post irradiation storage of 10 days. Irradiated *Direct yellow 12 dye* solutions were placed in darkness at room temperature to check the stability



**Figure 4.** The absorbance of acidic direct yellow 12 dye solution versus storage time in darkness.



**Figure 5.** The absorbance of alkaline direct yellow 12 dye solution versus storage time.



**Figure 6.** The absorbance of neutral direct yellow 12 dye solution versus storage time in darkness.

response during period of 10 days. The absorbance of solutions (pH-5.5 & pH-12.5) decreased for 2 or 3 days, afterwards dye solution showed stable behavior up to ten days. Figure 4 and 5 show the absorbance of acidic and basic *Direct yellow 12 dye* versus storage time. It is clear that the post irradiated acidic and basic solution when stored in darkness for the studied period give better stability response as compared to dye solution stored at high and low temperatures.

The neutral oxygenated *Direct yellow 12 dye* solutions (pH-7) give the best stability response during storage for 10 days. Neutral solution was more stable than acidic and basic solution indicating that the solution must be made neutral and it must be stored in dark environment as shown in the Figure 6.

## Conclusions

Dosimetric characterization of oxygenated *Direct yellow 12 dye* was investigated as its possible use as a gamma ray dosimeter in dose range 1 to 6 kGy. The solution did not show radiolytic bleaching in dose range of 1 to 6 kGy which indicates that it can be used for high dose ranges upto 10 kGy. The solution under goes thermal degradation during storage at high temperature indicating that the solution must be stored in low temperature or in darkness to avoid thermal degradation of dye's solution.

**References**

1. Parwate, D. V.; Sarma, I. D.; Batra, R. J. *Rad. Measur.* **2007**, *42*, 1527.
  2. Rauf, M. A.; Ashraf, S. S. *J. of Hazard. Mat.* **2008**, *166*, 6.
  3. Khan, H. M.; Anwar, M.; Chaudhry, Z. S. *Rad. Phys. Chem.* **2002**, *63*, 713.
  4. Bagyo, A. N. M.; Andayani, W.; Winarno, H.; Katrin, E.; Soebianto, Y. S. *Int. J. Env. Consc. Design Manufac.* **2004**, *12*, 45.
  5. Kovacs, A.; Wajnarovits, L.; Kurucz, C.; Al-Sheikhly, M.; McLaughlin, W. L. *Rad. Phys. Chem.* **1998**, *52*, 539.
  6. McLaughlin, W. L.; Kosanic, M. *Int. J. Appl. Rad. Isotopes.* **1974**, *25*, 249.
  7. McLaughlin, W. L.; Boyed, A. W.; Chadwick, K. H.; McDonald, J. C.; Miller, A. *Dosimetry for Radiation Processing*; Taylor and Francis: London, 1989; Vol. 3, pp 402-406.
  8. Khan, H. M.; Tabassum, S.; Wahid, M. S. *J. Rad. Anal. and Nucl. Chem.* **2009**, *3*, 635.
  9. Barakat, M. F., Banna, M. E. *Int. J. Low Rad.* **2007**, *4*, 286.
  10. Kattan, M.; Daher, Y.; AlKassiri, H. *Rad. Phys. Chem.* **2007**, *76*, 1195.
  11. Kattan, M.; Kassiri, H.; Daher, Y. *Appl. Rad. Isotopes.* **2011**, *69*, 377
  12. Kent, J. A. *Handbook of Industrial Chemistry*, 10<sup>th</sup> ed.; Plenum Publishers: New York, 2003; p 892.
-