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Research Article

A Study of Radiolysis Induced Degradation of a Synthetic Dye in Aqueous Solution Irradiated with Gamma Radiation

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Abstract: Wastewater discharged by textile industries contains harmful stubborn dyes at high concentration. The majority of dyes used in the textile industries are non-degradable; therefore, efficacious treatment of these colors can not be accomplished by customary processes. Radiation treatment has been viewed as a promising procedure for the treatment of industrial waste effluents. In this research, the synergistic effect of gamma radiation on the degradation of reactive black B (BB) dye has been discussed as a function of radiation dose. A UV-VIS spectrophotometer was used for spectrophotometric analysis of sample solutions. Cs137 gamma radiation source was used to irradiate the sample solutions within 0.2-100 kGy dose range. The experimental results showed the effective degradation of BB dye upon irradiation as the absorbance of the sample soltuions was decreased from 1.9 to 0.08; while %decoloration (%Đ) was increased from 23 to 97% within the selected gamma dose range.

Keywords: Radiolysis, Dye, Gamma radiation, Degradation, Decoloration.

1. INTRODUCTION

Dyes (colors) are visible pollutants, the presence of their causative compounds are undesirable in water. Waste water from textile industries is a serious issue; therefore, its proper remediation is necessary to avoid the biological, chemical as well as physical hazords. Textile dyes are non-biodegradable and chemically stable in light as well as to microbial attack due to the high concentrations of organic dyes in industrial wastewater [1]. Degradation of these synthetic dyes can make water suitable for reuse in industrial or municipal purpose. For effective treatment of industrial wastewater from textile industry containing numerous types of synthetic dyes; various techniques have been developed, including biological, physical and chemical methods. Biological treatments are slow and expensive which require long periods to degrade colorants of wastewater. Physical treatment methods can only transfer pollutants to some other kind of waste; which present the disposal problems. Chemical techniques are highly effective as compared to biological and physical treatments and have proven as a promising approach to treat industrial wastewater.

Extensive research work has been carried out in literature on radiation-induced degradation of aqueous solutions of dyes. Decoloration and degradation of aqueous solution of Reactive Red 120 dye (RR 120) upon gamma irradiation were investigated under appropriate conditions. Decoloration was more efficient under reducing condition. The extent of decoloration for both aerated and oxygen saturated solution was found almost identical [2]. The decoloration and degradation of four synthetic dyes (i.e., direct blue

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4GL; direct green 5GLL; reactive blue RB19; reactive yellow 3RF) after dyeing cotton fabric by low energy electron beam was investigated. The dye solutions were decolorized effectively in presence of H_2O_2 than in its absence. The data of chemical oxygen demand (COD) and total organic carbon (TOC) exclusion confirm the higher effectiveness of electron beam with respect to gamma irradiation [1]. The aqueous solutions of Reactive Blue 15 (RB15) and Reactive Black 5 (RB5) were irradiated within 0.1–15kGy gamma dose range. For lower concentration (50ppm) of dye solutions, the degree of decoloration was seemed to be 100% after 1 and 15kGy doses for RB5 and RB15, respectively [3].

Gamma-irradiation is a powerful, cost-effective and eco-friendly remedy as compare to other processes for wastewater treatment [4]. It is an established fact that aqueous solutions of synthetic dyes undergo color changes (decoloration) when exposed to gamma radiation [5-8]. The present work was carried out to check the degradation of Reactive Black B dye in terms of change in absorbance (A) and %decoloration (%Đ) of the sample solutions. In addition, the use of the degradation data for development of a radiation dosimeter has also been considered.

2. MATERIALS AND METHODS

2.1 Sample Preparation and Pre-Irradiation Treatments

The known mass (i.e., 0.125 gram) of Reactive Black B (BB) (MW: 991.82 amu; Molecular Formula: $C_{26}H_{21}N_5NaO_{19}S_6$) dye was liquefied in one litre of deionized water. Further experimental scheme was same as followed by Hayat et al [9]. Sample solutions having pH 7 were prepared and stored in dark for spectrophotometric analysis. Table 1 gives the complete description of utilities and their availability.

2.2 Sample Irradiation

Cs137 gamma radiation source was utilized for irradiation purposes [9-13]. The sample solutions were exposed to different gamma radiation doses within 0.2-100 kGy dose range. Table 2 gives the complete description of irradiation doses.

3. RESULTS AND DISCUSSION

3.1 Radiolysis of Aqueous Solutions

Water radiolysis causes the production of intermediate species (i.e., H_2, H_2O_2, H^+, OH^-, e_{aq}^-, •OH •H); and the amount of these species depend upon the linear energy transfer value of the radiation [15]. The response of absorbance (A) of BB at different irradiation doses is demonstrated in figure 2, 3 and 4 for low, intermediate and high dosimetry, respectively. Radiolysis of aqueous solutions of BB dye causes the deformation and brakage of the bonds of dye molecule; therefore, absorbance (A) of sample solutions is decreased with respect to absorbed dose (D).

The value of absorbance (A) is decreased from 1.9 to 0.08 with respect to absorbed dose (D) within 0.2-100 kGy gamma dose range; and hence gives the evidence of the presence of almost completely

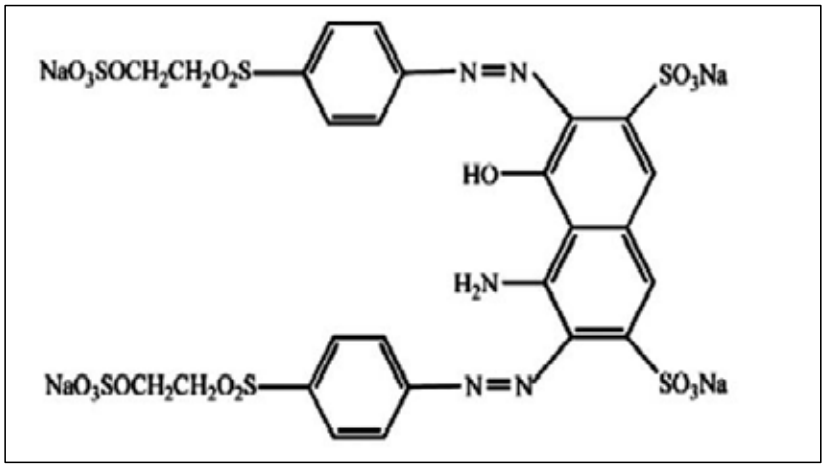

Fig. 1. Molecular strcture of BB dye

Table 1. Description of utilities and their availability

Utilities	Name	Availability
Solute	Reactive Black B	Kamal Industries Pvt. Ltd., Pakistan
Solvent	Deionized water	Pakistan scientific traders, Faisalabad, Pakistan
Acid	HCl (1 molar solution)	Pakistan scientific traders, Faisalabad, Pakistan
Base	NaOH (1 molar solution)	Pakistan scientific traders, Faisalabad, Pakistan
pH Meter	Hanna HI 83141	Department of Physics, University of Faisalabad, Pakistan
Spectrophotom-eter	CECIL 7200	Department of Physics, University of Faisalabad, Pakistan
Radiation Source	Cs-137	Nuclear Institute of Agriculture and Biology, Faisalabad, Pakistan
Storage Device	Black Box	Department of Physics, University of Faisalabad, Pakistan

destructed dye molecule in exposed solutions.

The BB dye belongs to di-azo group of synthetic dyes and has intense color due to N=N and extent of conjugation present in dye molecule. Primarily, the decoloration of azo dyes is resulted from the destruction of N=N. The •OH radicals are the most important oxidizing and reactive agents. The radiolysis yield is highest for •OH radicals when the aqueous solutions of dyes are irradiated by gamma radiation. Furthermore, hydrated electrons (e_{aq}^-) may react with the dye and form a semi-reduced (SR) species. The SR species may interact with the products of dye formed by the reactions with •OH radicals; reversible process can take place and reproduce the initial substance; and hence, coloration may be observed at final stage of the experiment [15].

The %Đ of dye solutions was calculated according to the formula adopted by Sun et al [16]. The %Đ of BB is 23% at 0.2 kGy; this percentage is enhanced gradually with respect to absorbed dose (D). At 1 kGy dose, the %Đ is increased to 90% within the low dosimetry. The value of %Đ is reached to 96 % within intermediate dosimetry; while 97% decoloration is achieved within high dosimetry. The sample solutions become almost colorless within 8-100 kGy gamma dose range; which shows the complete degradation of color

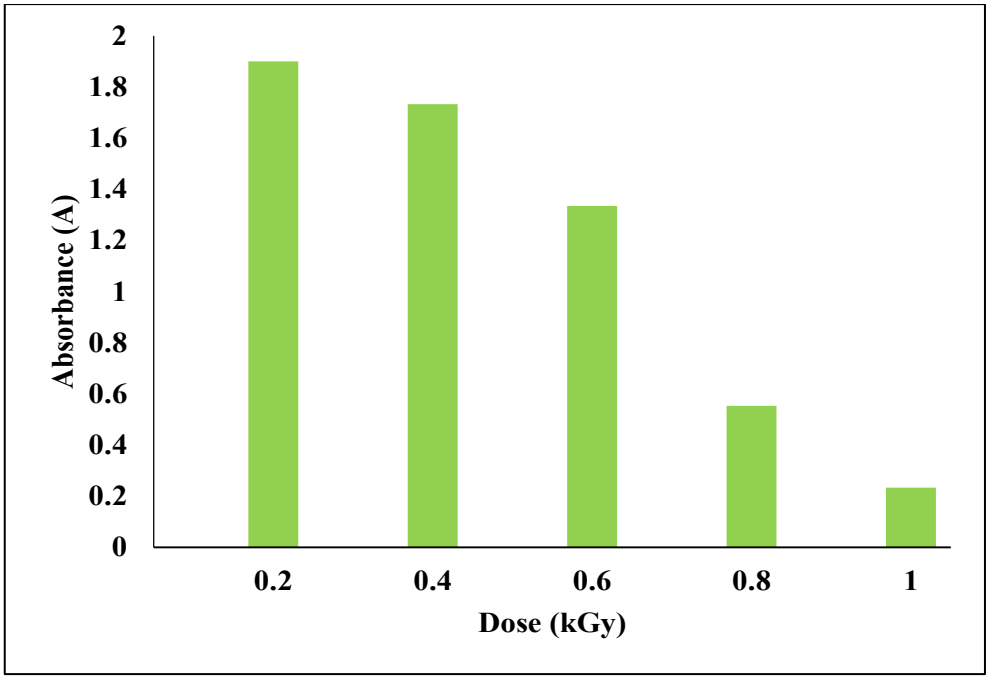

Fig. 2. Decrease in absorbance (A) upon different radiation doses within low dosimetry range

Table 2. Description of radiation doses

Dose (kGy)	Range	Dose (kGy)	Range	Dose (kGy)	Range
0.2	Low Dosimetry	2	Intermediate Dosimetry	20	High Dosimetry
0.4		4		40	
0.6		6		60	
0.8		8		80	
1		10		100	

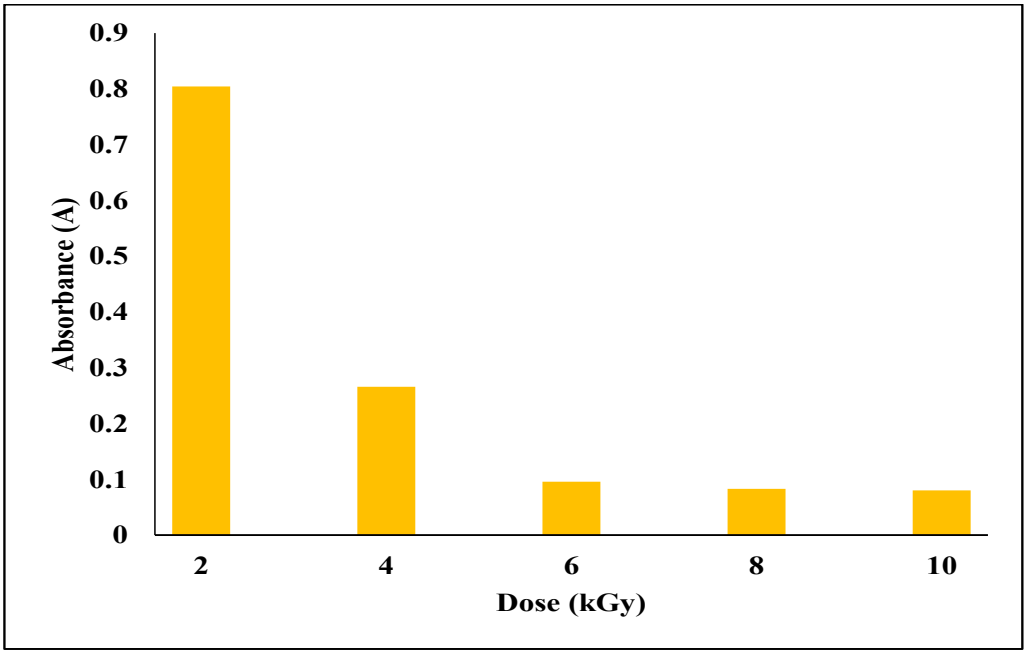

Fig. 3. Decrease in absorbance (A) upon different radiation doses within intermediate dose range

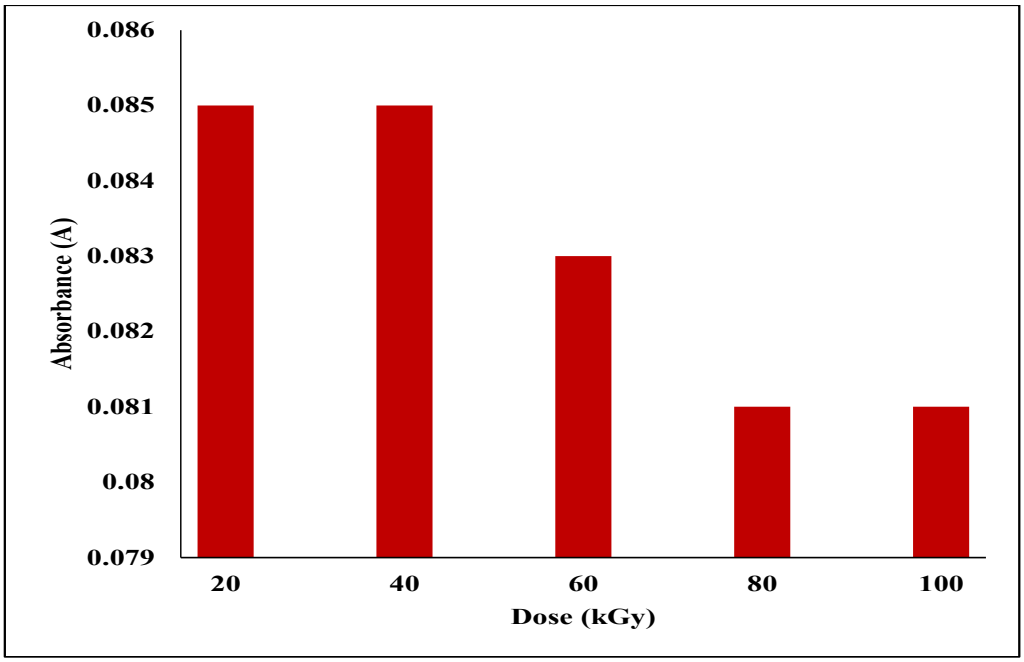

Fig. 4. Decrease in absorbance (A) upon different radiation doses within high dose range

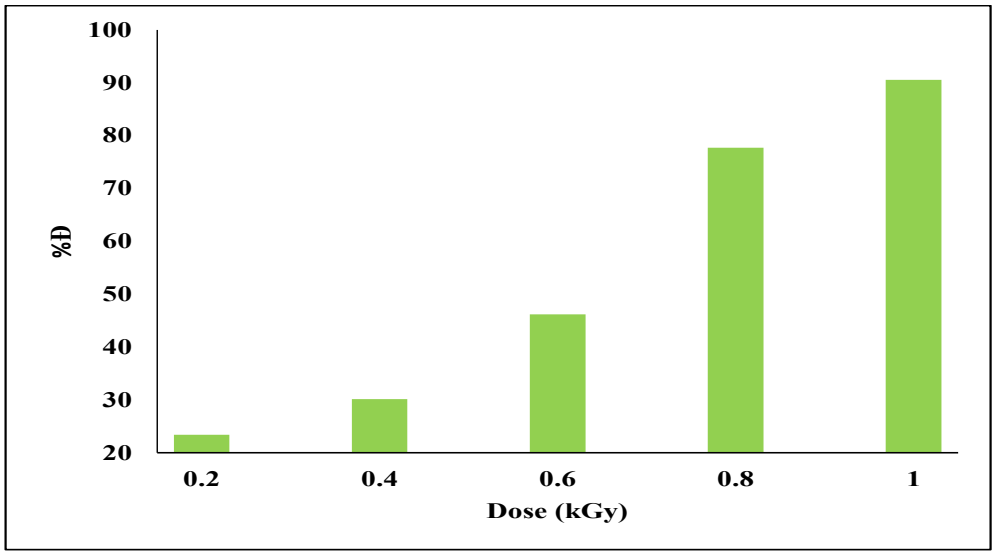

Fig. 5. Value of %Đ upon different radiation doses within low dosimetry range

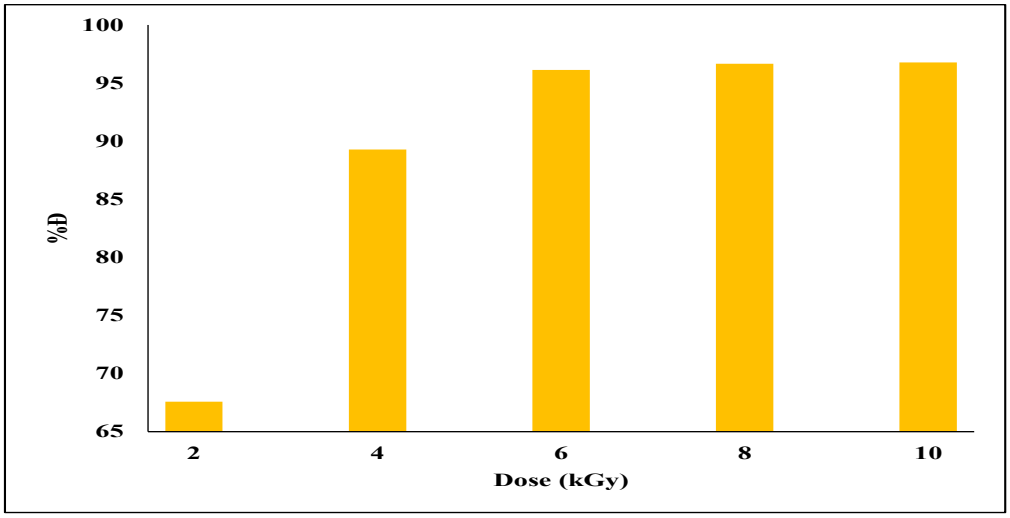

Fig. 6. Value of %Đ upon different radiation doses within intermediate dosimetry range

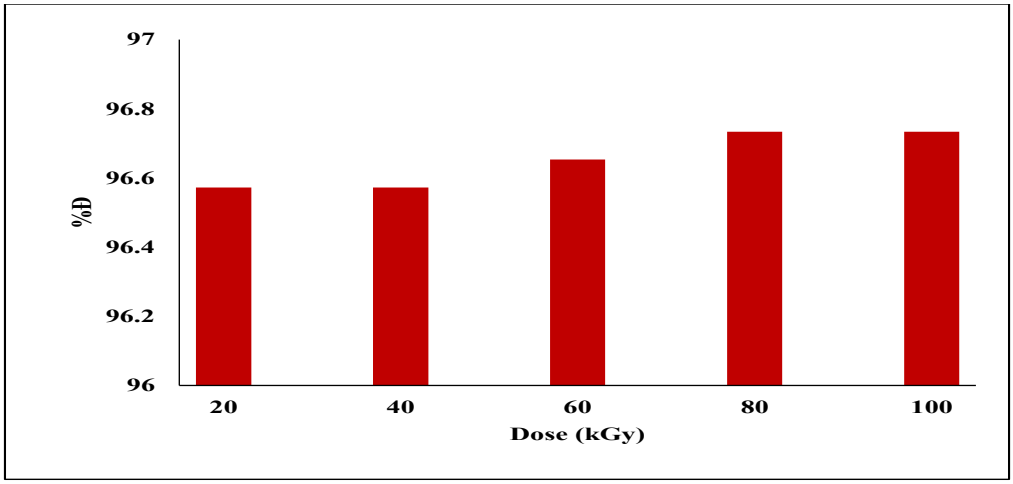

Fig. 7. Value of %Đ upon different radiation doses within high dosimetry range

substance in the exposed sample solutions.

4. CONCLUSION

The aqueous solutions of Reactive Black B (BB) dye were exposed to different gamma radiation doses within the selected dose range. The experimental results showed that the BB dye was degraded effectively upon gamma irradiation. The absorbance (A) of the sample solutions of BB was reduced from 1.9 to 0.081; while the % decoloration (%Đ) was increased from 23 to 97% within the selected dose range. Hence, wastewater containing BB can be treated by gamma radiation: however, the affective dose range would vary with the concentration of BB in solution. Variation in the value of absorbance (A) and % decoloration (%Đ) is dramatic; therefore, the sample solutions can also be used for dosimetric purposes within selected dose range.

5. ACKNOWLEDGMENT

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