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EFFECTS OF RADIATION ON WASTEWATER FROM TEXTILE INDUSTRIES IN GHANA

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Abstract. Wastewater samples from three textile industries in Ghana were progressively irradiated in a gamma irradiator of dose rate 7.8 kGy/h. Gamma irradiation alone was done, and also in combination with hydrogen peroxide, sodium peroxide and ferrous ammonium sulphate. Preliminary work involved irradiation of model aqueous solutions of six textile dyes commonly used in Ghana. The dyes were Cibacron Yellow 6G, Cibacron Violet 2R, Basilen Blue P 5R, Basilen Brown P 2R, Solidazol Red RB, Acramin Green FB. Colour and pH of the wastewater and dye solutions were found to decrease with irradiation. Decolouration of the wastewater improved further when irradiation was carried out in combination with the chemical agents. Ferrous ammonium sulphate showed the most improved decolouration. Values of chemical oxygen demand (COD) of the wastewater were found to decrease with irradiation.

1. INTRODUCTION

Indiscriminate discharges of untreated wastewater into the environment by industries in Ghana are now a great concern. It was estimated that textile industries alone discharge about 72.5×10^6 litres of wastewater daily containing high levels of toxic and non-biodegradable dyestuffs and other chemicals [1]. This situation has caused destruction of life in some lagoons, and reduced soil fertility of potential farmland in other areas of the country.

To avert this environmental problem the Environmental Protection Agency of Ghana came out with sector specific effluent quality guidelines for discharge into the environment. Industries are, therefore, under obligation not only to treat their wastewater but also adopt efficient treatment methods. Wastewater treatment methods such as, filtration, sedimentation and chlorinating, which are practised by some textile industries, are reported to be ineffective and environmentally dangerous [2, 3]. It has, therefore, become expedient to study alternate methods that are efficient and environmentally friendly. Earlier studies [4–7] have shown that coloured materials undergo bleaching or decrease in colour when exposed to ionizing radiation. In principle, therefore, gamma and e-beam irradiation can be considered as alternate method of treatment of wastewater from textile industries. This work, therefore, examines the potential of gamma irradiation, and in combination with some chemical agents for decolouration and decomposition of dyestuffs and other organic pollutants in wastewaters from textile industries in Ghana.

2. EXPERIMENTAL

2.1. Materials

Five soluble dyes — Cibacron Yellow 6G, Cibacron Violet 2R, Basilen Blue P 5R, Basilen Brown P 2R, Solidazol Red P RB, and a disperse dye, Acramin Green, were obtained from three major textile industries in Ghana. The dyes were manufactured in Germany. Untreated wastewaters labelled GT.1, GT. 2, and GT. 3 were collected from the same three industries. Analytical grade chemicals: 30% Hydrogen peroxide, 30% Sodium peroxide solution and 30% ferrous ammonium sulphate solution were used.

2.2. Methods

Model aqueous solutions of concentrations 50, 100, 150, and 200 ppm that are close to the content of dyes in industrial wastewater were prepared with each dye. The pH of the dye solutions was measured using WTW pH meter model 523. A Unicam SP 1800 UV/vis-spectrophotometer was used to scan the absorption spectra of each dye solution over the wave length range 200-800 nm, and the optical densities at the characteristic wave lengths were measured.

200 ml of each dye solution was transferred separately into 250 ml leak-proof polypropylene bottles. The bottles were then irradiated progressively to a maximum dose of 6 kGy in a gamma irradiator of dose rate 7.8 kGy/h available at the Ghana Atomic Energy Commission. Twenty-four hours after every irradiation interval, the pH and optical absorption at the characteristic wavelengths of the dye solutions were measured. The wastewaters were similarly irradiated progressively to a maximum dose of 20 kGy by gamma irradiation alone and in combination with each chemical. The parameters, pH and optical absorption at the characteristic wavelength, were measured after every irradiation interval. Chemical oxygen demand (COD) of the wastewaters was determined before and after each irradiation interval by a standard procedure [8].

3. RESULTS AND DISCUSSION

3.1. Absorption spectra

The optical absorption spectra of the unirradiated dye solutions showed strong absorption at the following wavelengths: Cibacron Yellow 6G, 432 nm; Basilen Brown P 2R, 460 nm; Solidazol Red P RB, 530 nm; Cibacron Violet 2R, 560; Basilen Blue P 5R, 570 nm; Acramin Green FB, 650 nm. Each dye solution showed a second absorption band at about 230 nm. On irradiation the absorption band at 230 was not affected even at 6 kGy. The absorption bands at 430, 460, 530, 560 and 570 nm were found to decrease rapidly with increasing irradiation dose. The decrease was more rapid for the lower concentration (50 ppm) dye solutions than the high concentration solutions. The maximum absorption band of the lowest concentration solution disappeared almost completely at a dose of 2 kGy. For the highest concentration (200 ppm) dye solution, the maximum absorption bands disappeared after 4-kGy irradiation dose. From other studies [9, 10], the absorption band at 230 nm was attributed to substituted aromatic rings of the dye molecule. Similarly, the absorption bands at 430, 460, 530, 560 and 570 nm were attributed to azo groups and their auxochromic substitutes. The observed changes in the absorption bands in the visible region with irradiation dose, therefore, suggest destruction of only the chromophoric groups with little or no effect on the substituted aromatic rings of the dye molecule [4].

The optical absorption spectra of the pigment (Acramin Green FB) solution, with strong absorption bands at 230 nm and 650 nm, was totally unaffected by irradiation even after 6 kGy dose. This would imply that irradiation could not promote any breakdown of the pigment.

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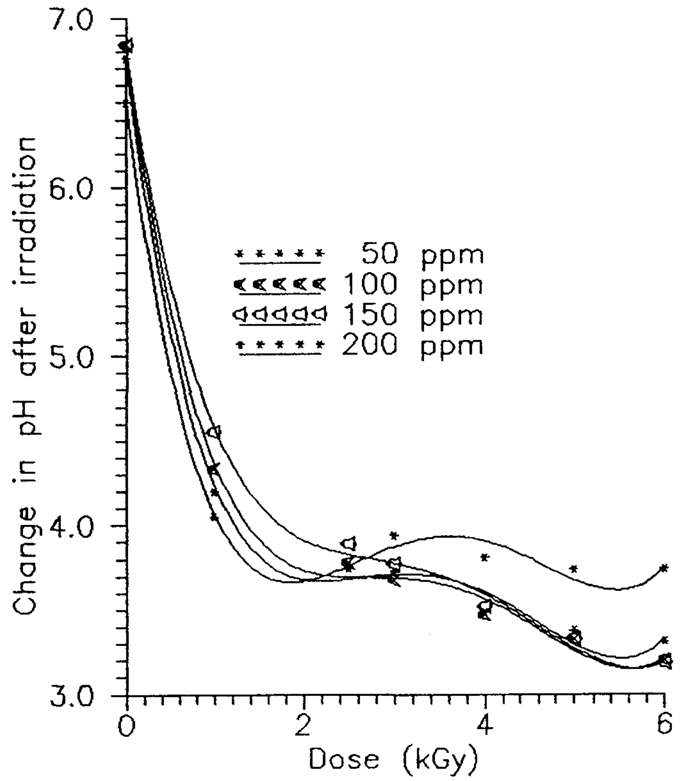

FIG. 1. Change of pH with irradiation doses (kGy) of various concentrations (ppm) of Cibacron Yellow 6G.

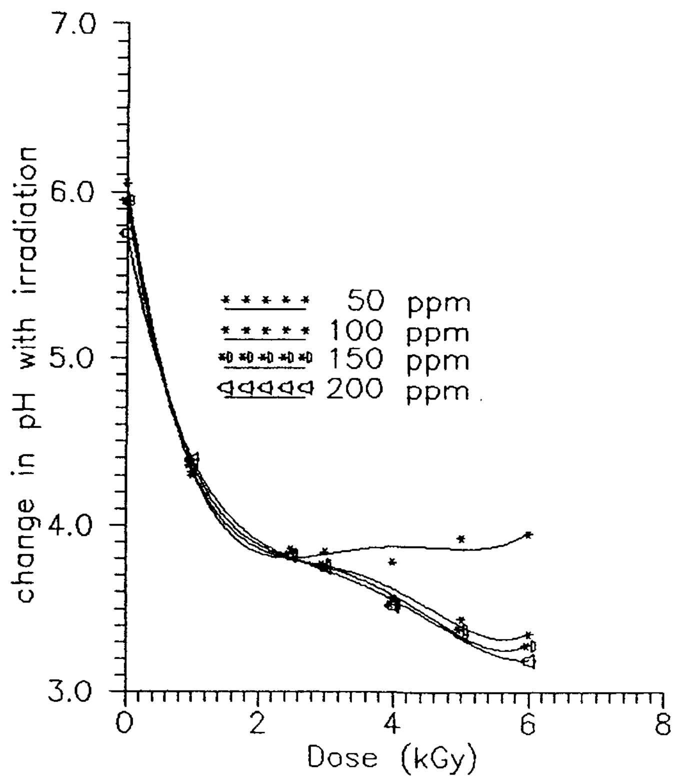

FIG 2. Change in pH with irradiation doses (kGy) of various concentrations (ppm) of Basilen Blue P 5R.

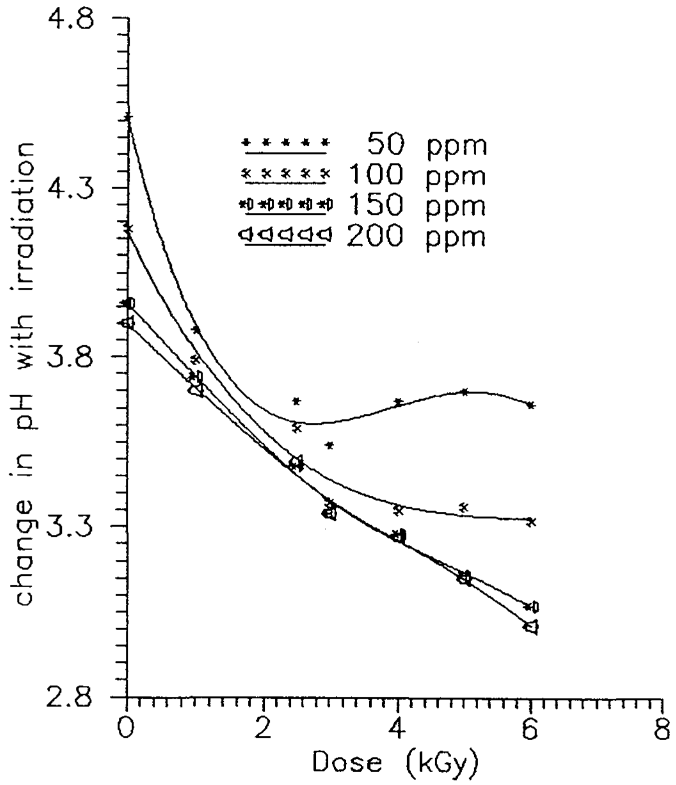

FIG. 3. Change in pH with irradiation doses (kGy) of various concentrations (ppm) of Solidazol Red P RB.

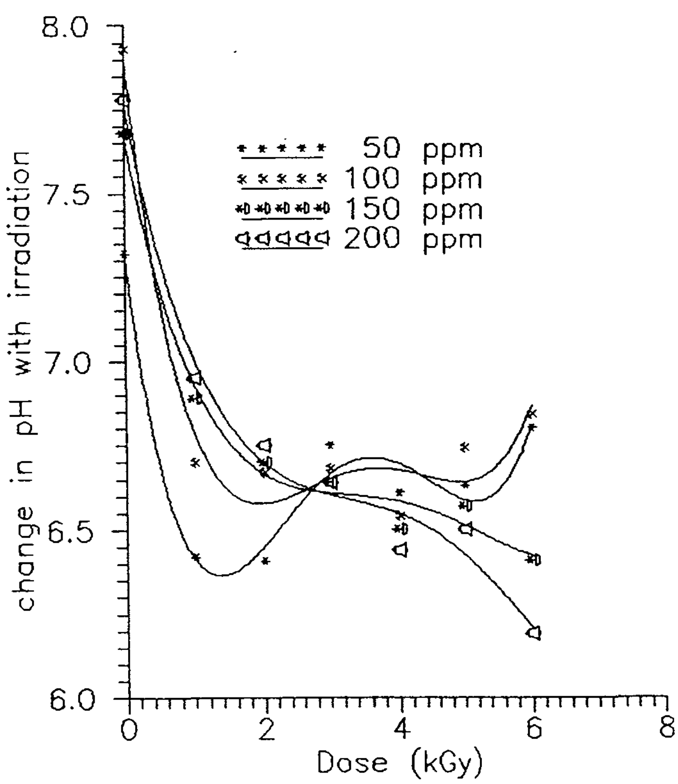

FIG 4. Change in pH with irradiation doses (kGy) of various concentrations (ppm) of Basilen Brown P2R.

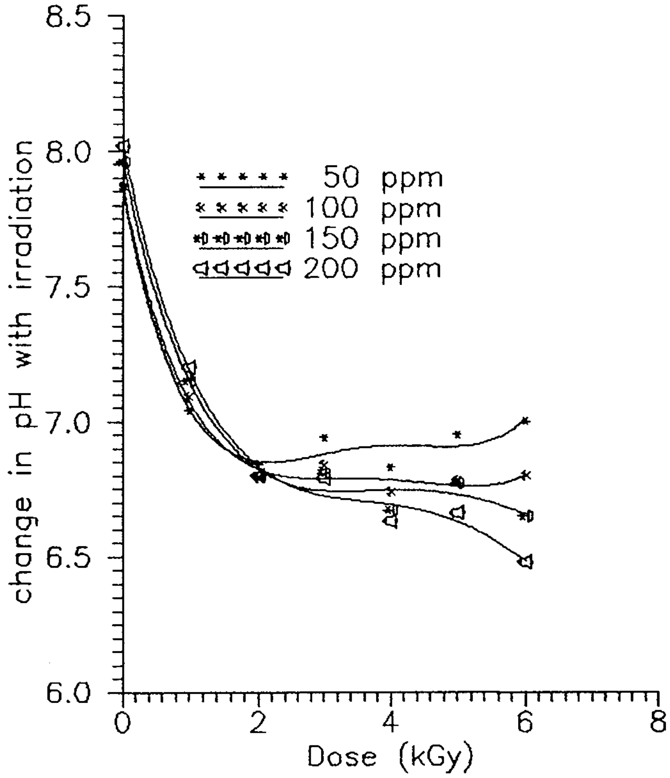

FIG. 5. Change in pH with irradiation doses (kGy) of various concentrations (ppm) of Cibacron Violet 2R.

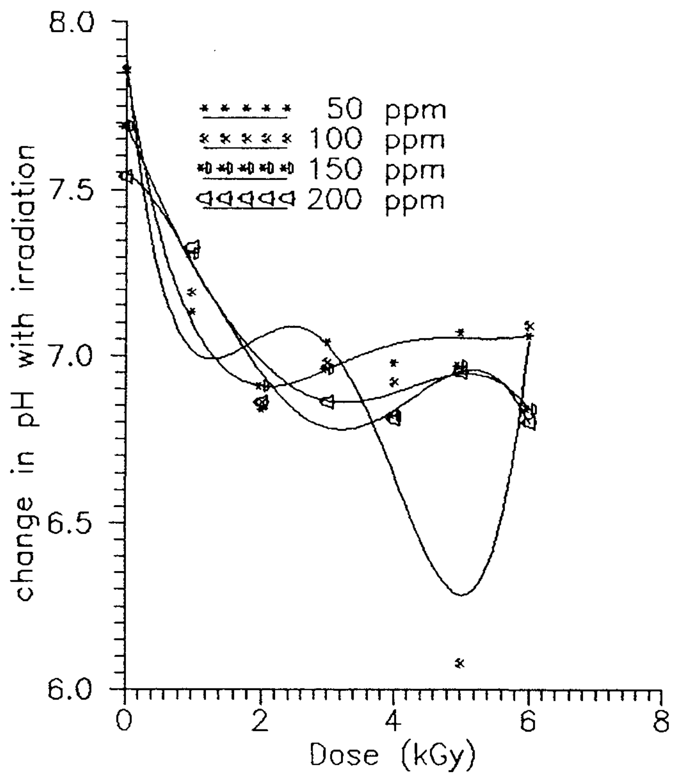

FIG 6. Change in pH with irradiation doses (kGy) of various concentrations (ppm) of Acramin Green FB.

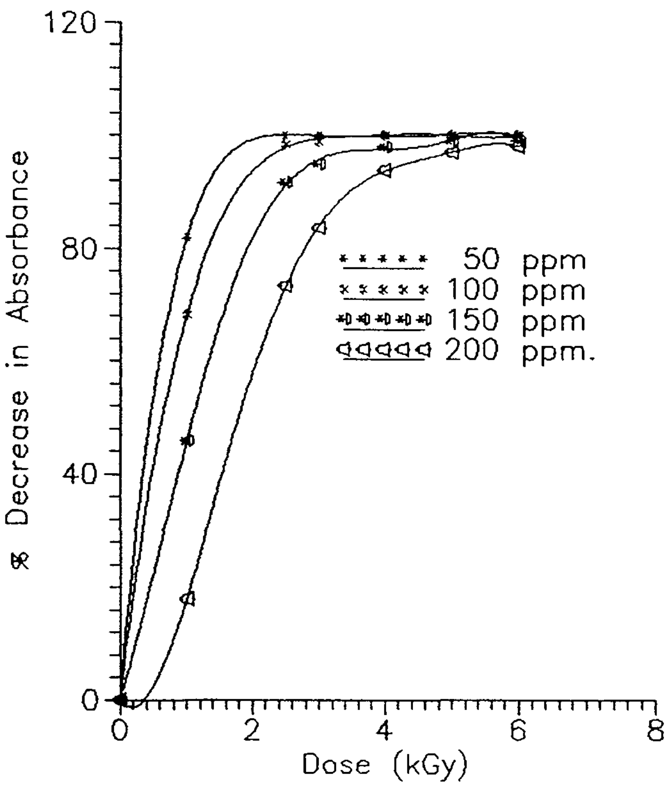

FIG. 7. Degree of decolouration (%) vs. doses (kGy) of various concentrations of Cibacron Yellow 6G.

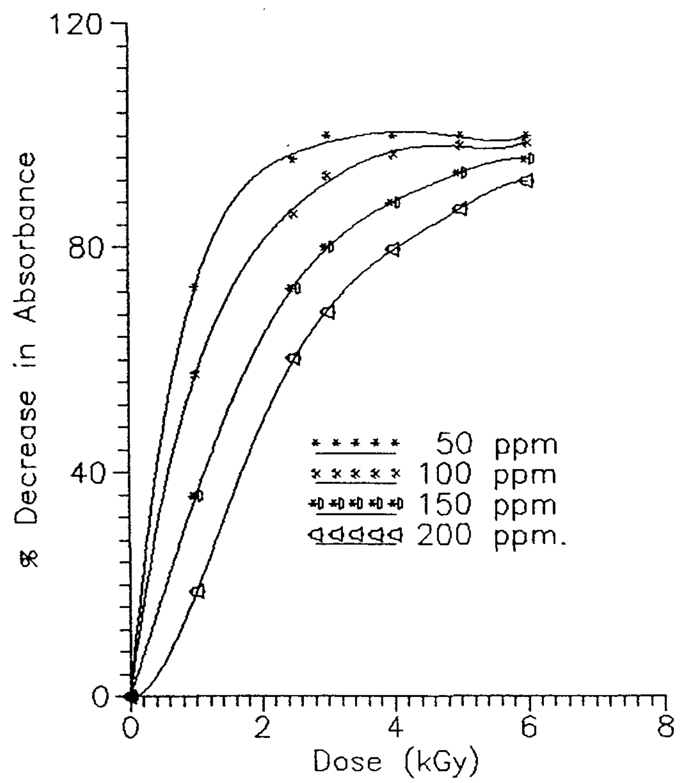

FIG 8. Degree of decolouration (%) vs. doses (kGy) of various concentrations of Basilen Blue P 5R.

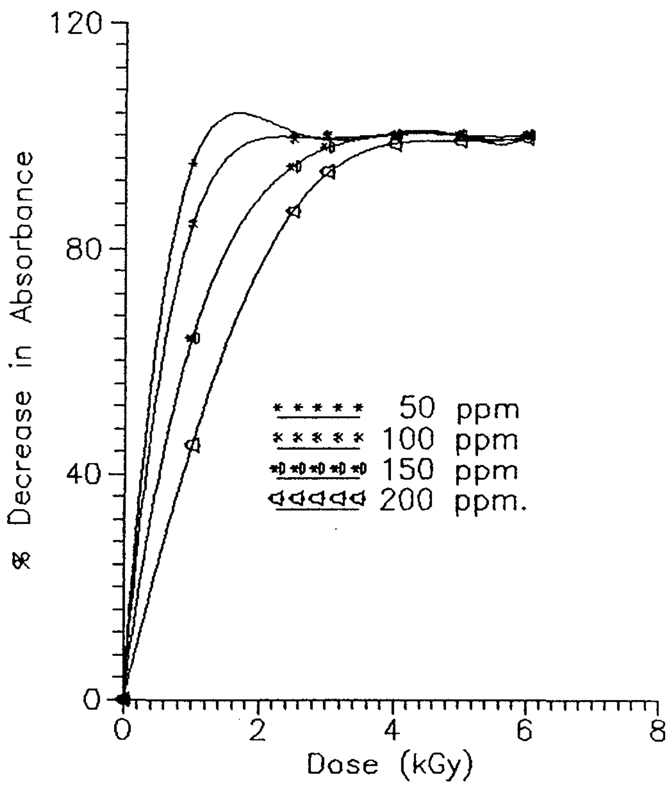

FIG. 9. Degree of decolouration (%) vs. doses (kGy) of various concentrations of Solidazol Red P RB.

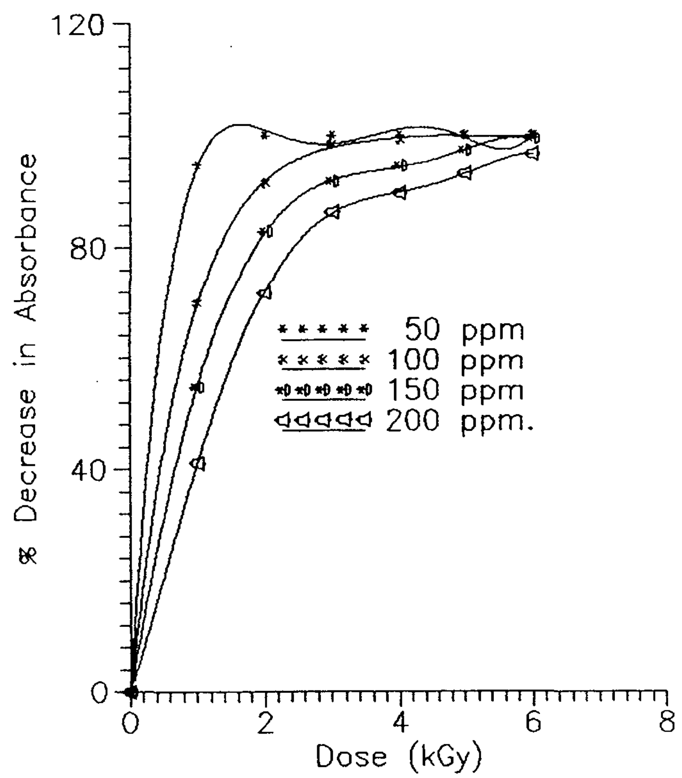

FIG 10. Degree of decolouration (%) vs. doses (kGy) of various concentrations of Basilen Brown P2R.

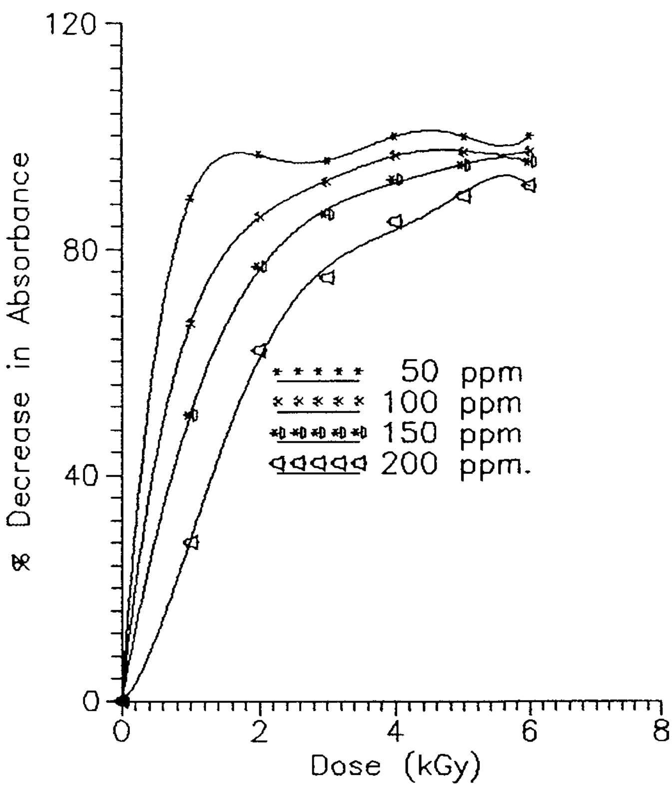

FIG. 11. Degree of decolouration (%) vs. doses (kGy) of various concentrations of Cibacron Violet 2R.

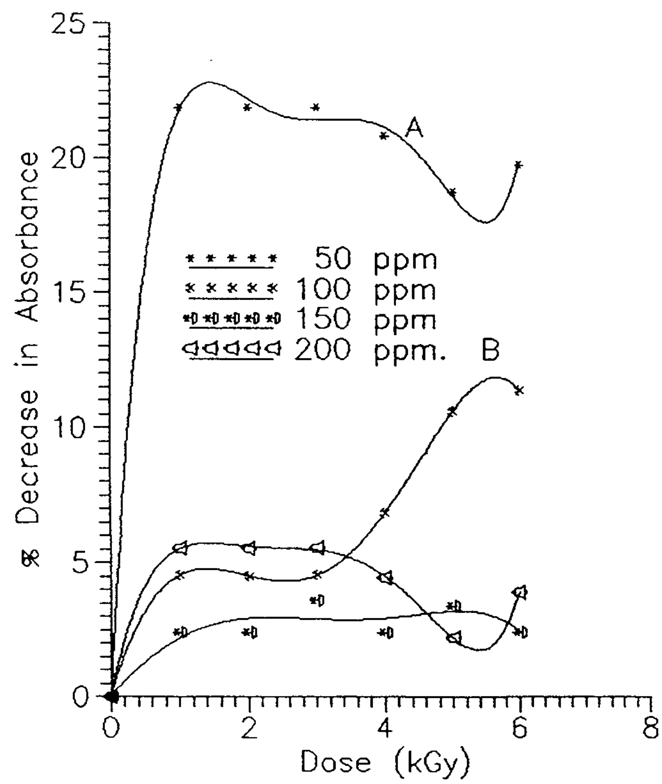

FIG 12. Degree of decolouration (%) vs. doses (kGy) of various concentrations of Acramin Green FB.

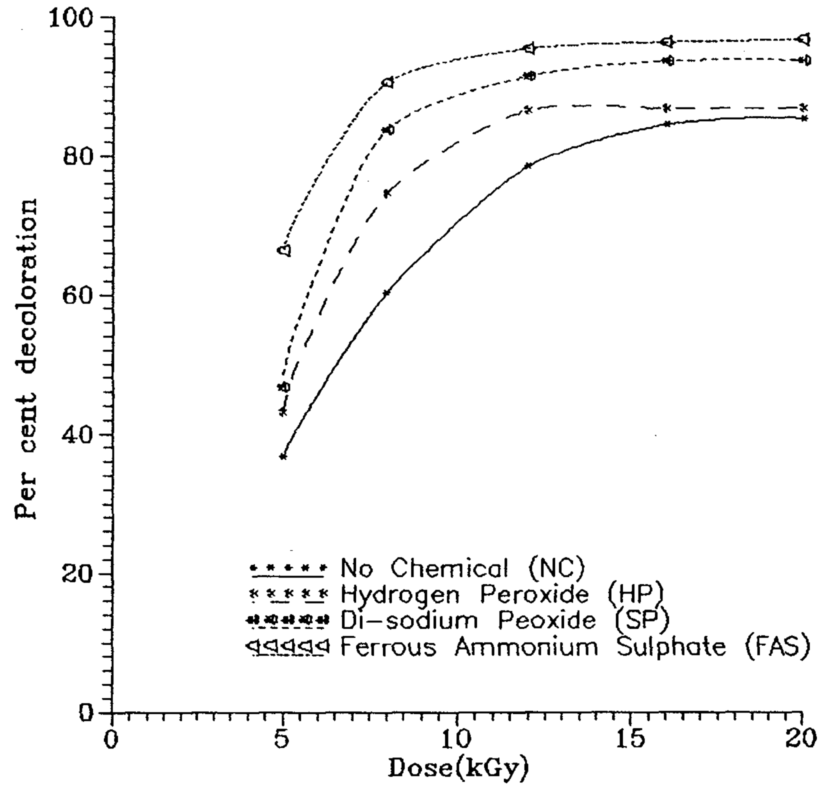

FIG. 13. Percentage decolouration of wastewater (GT.3) treated with irradiation in combination with chemicals.

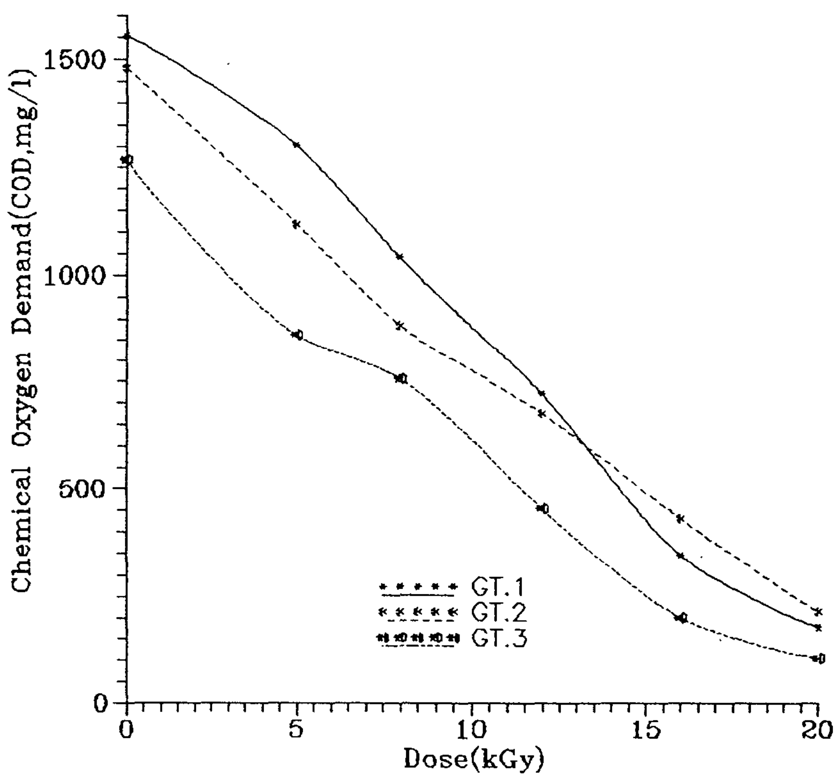

FIG 14. Change in chemical oxygen demand (COD, mg/l) of wastewaters GT. 1, GT. 2,ane GT. 3 with irradiation dose.

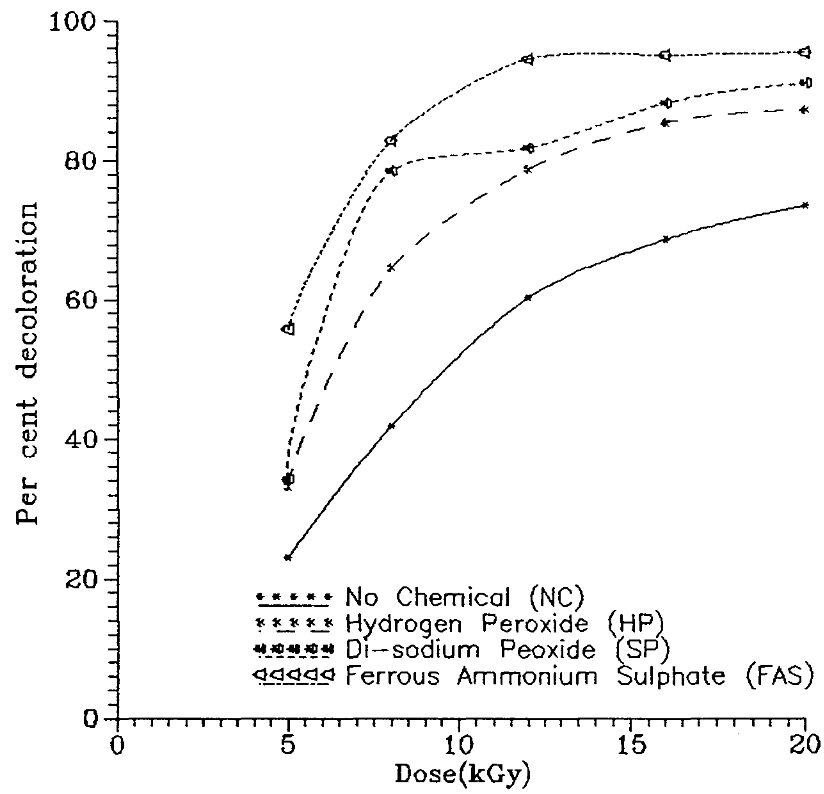

FIG. 15. Percentage decolouration of wastewater (GT.1) treated with irradiation in combination with chemicals.

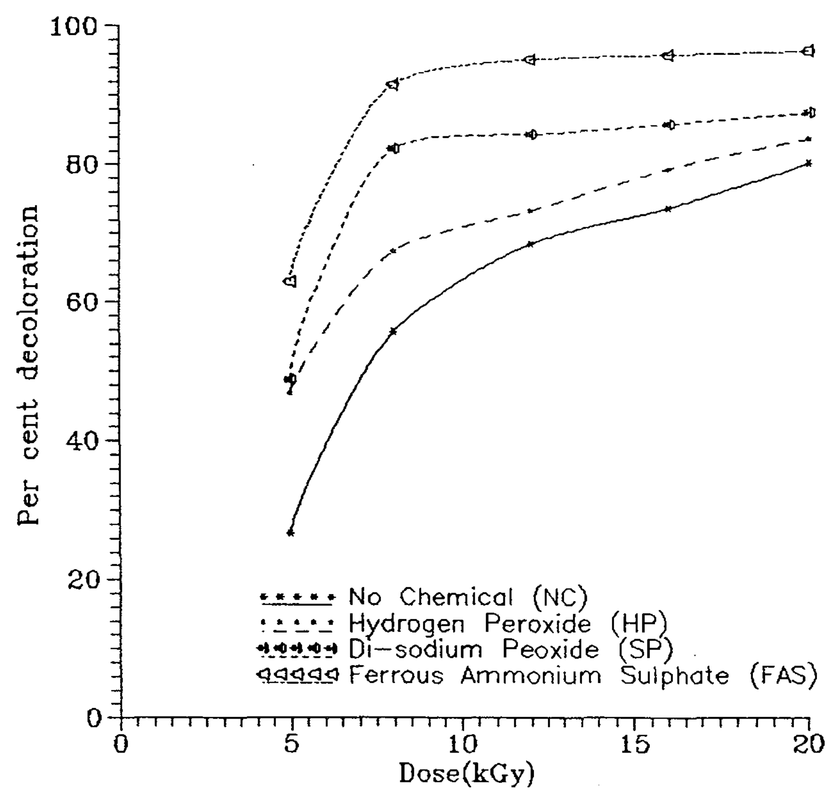

FIG 16. Percentage decolouration of wastewater (GT.2) treated with irradiation in combination with chemicals.

3.2. Effect on pH

In Figs 1–6 are presented changes in pH values with increase in irradiation dose for the dyes and pigment solutions. In all cases the pH decreased sharply after the first irradiation dose of 1 kGy. Thereafter, the pH values changed very slowly or remain constant with increase in irradiation dose. This suggests that organic acid compounds that were initially formed by destruction of the colour forming groups undergo further decomposition to smaller non-acidic molecules with increase in irradiation dose.

3.3. Degree of decolouration

The degree of decolouration of the dyes and pigment solutions with irradiation was estimated as the reduction in optical density at the characteristic wavelength where the absorbency was strongest. The results are presented in Figs 7–12. Decolouration was linear up to about 60 per cent for all the dye solutions. At the same irradiation dose, the lower the concentration of the dye solution, the higher decolouration was. For the pigment, only the solutions that have low concentrations showed some decolouration (Fig. 12). Solutions with high pigment concentration appeared not to be affected by irradiation. The pigment was largely present in the water in a separate phase. For this reason, its reactions with water radiolysis products were suppressed, and the pigment solution was observed to be stable to radiation in this study. Effect of gamma irradiation in combination with hydrogen peroxide, sodium peroxide and ferrous ammonium sulphate, respectively, on the colour of the wastewaters are shown in Figs 13–15. Hydroxyl radicals play very important role in radiation decomposition of organic pollutants in water [3]. In this study, therefore, hydrogen peroxide and sodium peroxide were used to introduce additional OH radicals into the wastewater during irradiation. Improved decolourations of the wastewaters were achieved, as expected, compared to using only irradiation. Disperse dyes and other similar pollutants present in wastewater are in separate phase and will not react with water radiolysis products [6]. To overcome this problem in our study, ferrous ammonium sulphate was added to the wastewaters before irradiation to precipitate any disperse organic pollutant. In this way a much improved decolouration was achieved for all the wastewaters used in this study. It was also observed that high irradiation dose (20 kGy) was involved to achieve 90 per cent decolouration of the wastewaters. This could be attributed to the high concentration of dyes, with some in disperse form, in the wastewater. Besides, it is also possible that other organic pollutants were competing with the water radiolysis products, especially the hydroxyl radicals produced in the wastewater.

3.4. Chemical oxygen demand

The oxidation effect of radiation on organic pollutants in wastewater was determined by measurement of COD values with irradiation. The results are presented in Fig. 16. It was observed that COD values of the wastewaters studied in this work decreased with increased irradiation dose. The decrease in COD values confirms the importance of oxidation in irradiation of wastewaters.

4. CONCLUSION

The potential of gamma irradiation for decolouration and decomposition of textile dyes and similar organic compounds in industrial wastewater in Ghana has been investigated. Complete decolouration of model aqueous solutions of soluble dyes was achieved with irradiation dose of 6 kGy. The irradiation dose required for maximum decolouration depended on the concentration of the solution. Decolouration of aqueous solution of pigment was not achieved by irradiation condition of this study. Improved decolouration of wastewaters from textile industries was achieved by gamma irradiation in combination with hydrogen peroxide, sodium peroxide and ferrous ammonium sulphate, respectively, compared to gamma irradiation alone. Ferrous ammonium sulphate used in combination with irradiation produced the best decolouration at any given irradiation dose. Irradiation promotes oxidation of organic compounds in the wastewaters. The higher the irradiation doses the more the oxidative effect and hence the higher the reduction in COD value of the wastewater.

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