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EFFECT OF GAMMA AND ELECTRON BEAM IRRADIATION ON TEXTILE WASTE WATER

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ABSTRACT

In this studies gamma and electron beam irradiation was used to treat textile waste water. Comparisons between both types of irradiation in terms of effectiveness to degrade the pollutants present in textile waste water were done. Prior to irradiation, the raw wastewater was diluted using distilled water to a target concentration of COD 400 mg/l. The sample was irradiated at selected doses between the ranges of 10 kGy to 100 kGy. The results showed that irradiation has significantly contributed in the reduction of the highly colored refractory organic pollutants. The COD removal at the lowest dose, 10 kGy was reduced to 390 mg/l for gamma and 400 mg/l for electron beam. Meanwhile, at the highest dose, 100 kGy, the COD was reduced to 125 mg/l for gamma and 144 mg/l for electron beam. The degree of removal is influenced by the dose introduced during the treatment process. As the dose increased, the higher the removal of organic pollutant was recorded. However, gamma irradiation is more effective although the differences are not significant between gamma and electron beam irradiation. On the other hand, other properties of the wastewater such as pH, turbidity, suspended solid, BOD and color also shows a gradual decrease as the dose increases for both types of irradiation.

Keywords: BOD, COD, electron beam irradiation, gamma irradiation, turbidity, wastewater

INTRODUCTION

Among manufacturing industries, the textile industry is one of the most complicated industries. One of the major problems faced by textile manufacturers is wastewater treatment. The combination of the processes and products makes the wastewater from textile plant contain many types of pollutants such as sizing agents, complexing agents, dyes, pigments, softening agents, stiffening agents, fluorocarbon, surfactants, oils, wax and many other additives which are used throughout the processes. These pollutants contribute to high suspended solid (SS), chemical oxygen demand (COD), heat, color, acidity and basicity. This wastewater can exert great environmental problems due to their high color, large amount of suspended solid and high chemical oxygen demand.

Existing conventional treatment using physical and chemical treatment is not capable of destroying or decomposing the recalcitrant and toxic organic pollutants but rather it transfers the pollutants from a liquid medium to a solid medium via the coagulation/chemical process. Biological methods are generally cheap, simple applications and often used to remove organics and color of textile wastewater [Kim et al., 2002]. However, this wastewater cannot be readily degraded by conventional biological processes, e.g. activated sludge process because the structure of most commercial dye compounds are generally complex and many dyes are non-biodegradable due to the chemical nature and molecular size [Kim et al., 2002]. Thus, ionizing radiation may be promising for the treatment of textile wastewater

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because the effect of radiation can be intensified in aqueous solution, in which the dye molecules are degraded effectively by the primary products formed through radiolysis of water [Solphan, 2001].

Ionizing radiation known as radiation that has sufficient energy to dislodge electrons from atoms and molecules and to convert them to electrically-charged particles called ions. Further reactions of these species, will lead to the formation of free radicals which are usually reactive and that eventually will lead to chemical reactions [Dahlan, 2001]. The aim of this study is to compare the effect of electron beam and gamma irradiation on textile wastewater in term of its effectiveness to degrade the existing recalcitrant and toxic organic pollutants. Gamma irradiation, also known as gamma rays (denoted as γ), is an electromagnetic radiation of high frequency which is produced by sub-atomic particle interactions. Gamma-rays have the smallest wavelengths and the most energy compared to any other wave in the electromagnetic spectrum [Fang, 1999]. The wastewater will be irradiated at the same selected doses by using electron beam and gamma ray and properties of the irradiated water will be examined.

EXPERIMENTAL

Sampling and sample preparation

Wastewater used in this research was obtained from a textile industry which is located at Rawang Integrated Industrial Park (RIIP), Malaysia. The sample was stored in a refrigerator at $4^{\circ}C$ before use. The sample was a mixture of wastewater produced from several processes such as washing, dying, waxing and rinsing. The content of the wastewater was unknown specifically for each individual pollutant and is being classified as a mixture of various chemicals. Prior to irradiation, the sample was diluted with distilled water to a targeted concentration of COD at 400 mg/l. Initial COD value was fixed at 400 mg/l for all the samples which was irradiated at different doses.

Irradiation

Gamma irradiation was conducted at room temperature. The sample was filled into a 500ml glass bottle and marked accordingly. The sample was irradiated using the following doses: 10 kGy, 15 kGy, 20 kGy, 25 kGy, 50 kGy, 75 kGy and 100 kGy. The sample bottles were placed on aluminum totes which automatically enter and leave the radiation room on a roller conveyor system. Totes are conveyed on two levels, lower and upper levels, around aColbalt-60 source using a two-pass system. This provides maximum utilization of the ionizing energy ensuring that samples are well exposed on all sides.

For electron beam irradiation, samples were filled in a tray and placed on the trolley, then transported to the irradiation chamber in order for the samples to be irradiated. According to the speed of conveyor and current (mA) of applied electron beam, the dosages of irradiation were adjusted. Irradiation of samples was conducted using Nissin, 1 MeV and 30 mA in a batch system. The speed of conveyor used was ranged 0 – 10m/min and the sample thickness was 3.0mm. The sample was irradiated using the following doses: 10 kGy, 15 kGy, 20 kGy, 25 kGy, 50 kGy, 75 kGy and 100 kGy.

Sample analysis

Samples were analyzed before and after irradiation. COD refers to the amount of oxygen required to chemically oxidize the organic matter contained in wastewater. To determine the COD, a sample was first digested using dichromate (HR range plus) in Hach reactor and COD value was determined by a Hach-2400 spectrophotometer. BOD measures the rate of oxygen uptake by micro-organism in a sample of wastewater and was measured at the temperature of 20 ^{o}C over an elapsed period of five days in the dark. It is not a precise quantitative test, but used widely as an indicator to measure water quality. pH of the sample was analyzed using a pH meter (WTW Multi 340i). Samples irradiated using gamma and electron beam were analyzed separately.

RESULTS AND DISCUSSION

Effect of irradiation dose to pH

The pH of textile wastewater which was collected from the industry was ranged from 10.00 to 10.25. The pH of samples after irradiation shows a reduction for both types of irradiation. At 10 kGy, the pH was 9.96 for gamma irradiation while the electron beam irradiation registered as 10.11 reading. As the dose is increased, the pH of wastewater gradually decreased as shown in Fig. 1. At the highest dose, the lowest pH was recorded. At 100 kGy, the pH was 7.04 and 7.59 for gamma and electron beam irradiation respectively. The reduction in pH depends on changes in structures of dye molecules present in the wastewater. The change of pH may be attributed to oxidizing products formed by degradation and this reaction is induced by ionizing irradiation [Pikaev et al., 1996]. The change in pH may also be due to water radiolysis (●OH, e^{-}_{aq}, H^{+}) that produces hydronium ions.

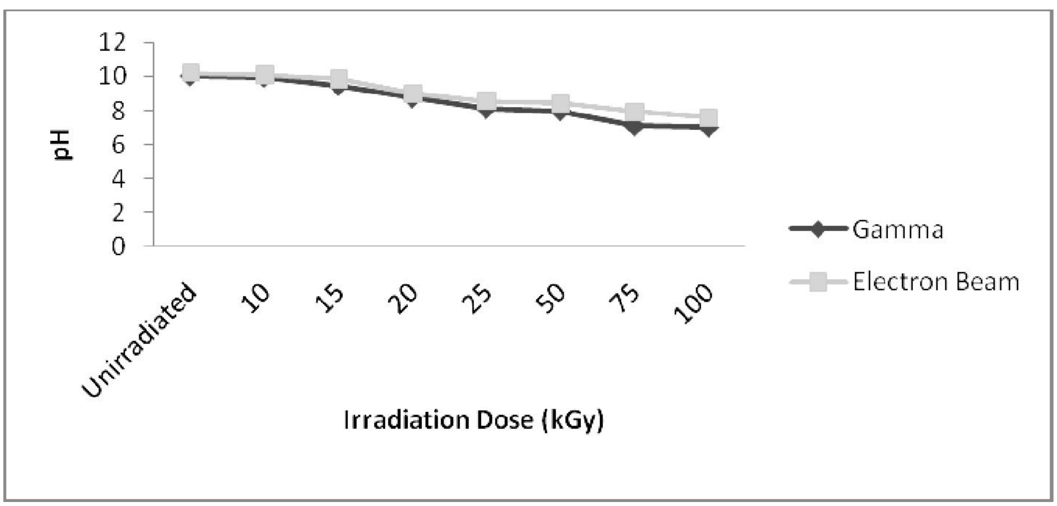

Fig. 1: Effect of irradiation dose on pH

Effect of irradiation dose in removal of COD

COD determines the amount of organic pollutant in water. The basis for the COD test is that nearly all organic compounds can be fully oxidized to carbon dioxide with strong oxidizing agent under acidic condition. Thus, reduction of COD suggests the decomposition of organic pollutant. There is reduction of COD observed after irradiation. At 10kGy, the COD was 390 mg/L and at 100kGy the value dropped to 125 mg/L for gamma irradiation. For electron beam irradiation, the COD was 350 mg/L at 10 kGy and 144 mg/L at 100kGy. The trend of reduction is shown in Fig. 2. When the wastewater was exposed to ionizing irradiation, the water molecule undergoes radiolysis process to produce ionized and excited water molecules and free electrons (reactive species). Reactions between pollutants and primary products of water radiolysis (●OH, e^-_{aq}, H^+) and secondary short-lived species formed from the pollutants causes the removal of pollutants from the wastewater. The mechanism is as follows [Buxton et al., 1998].

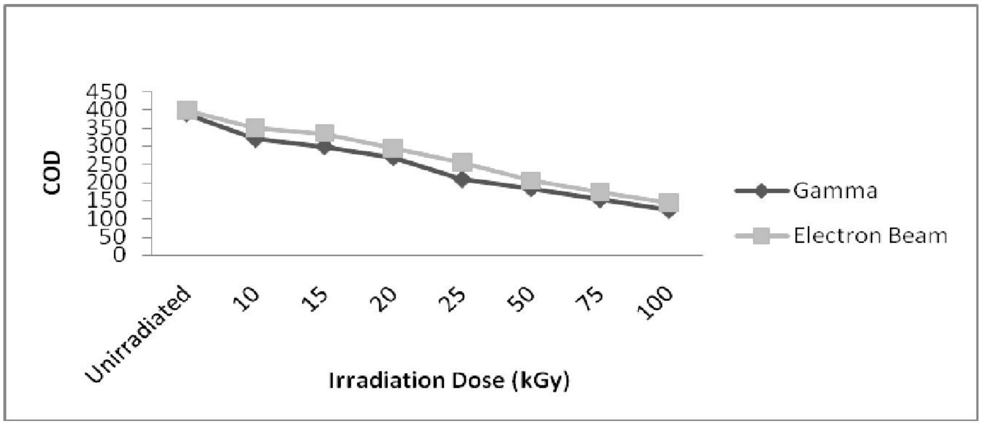

Fig. 2: Effect of irradiation dose on COD

Through the ionizing radiation process, the water molecule ionized:

$$H_2O \longrightarrow H_2O^+ + e^-_{aq}$$

The ionized molecules react rapidly to form hydroxyl radical:

$$H_2O^+ + H_2O \longrightarrow H_3O^+ + \bullet OH$$

$$HO_2\bullet \longleftrightarrow H^+ + O_2^{\bullet -}$$

Hydroxyl radical is the main reactive species which responsible for radicals-pollutants reactions. This leads to decomposition of pollutants. Hydroxyl radical have high potential as oxidizing agent to dehalogenation and cleavage of the chemical bonds [Anbar et al., 1967]. The quantity of water molecule which undergoes radiolysis associated with absorbed dose where more hydroxyl radical will be produced at higher dose. Therefore, higher amount of pollutants were decomposed at higher absorbed dose.

Effect of irradiation dose on turbidity and suspended solid

Turbidity is the cloudiness of a liquid caused by individual particles (suspended solid). The Turbidity of unirradiated textile wastewater was ranged from 5.05 – 5.25 NTU. At 10 kGy the turbidity was 5.23 NTU and 5.10 NTU for gamma and electron beam irradiation. As the dose of irradiation was 100 kGy, the turbidity was 3.57 NTU for gamma and 4.00 NTU for electron beam irradiation. The result of turbidity upon irradiation dose for both types of irradiation is shown in Fig. 3. This indicates that interaction of radicals with the dye particles result in pre-degradation of the dye particles. As the dose was further increased up to 100 kGy, a higher yield of complete degradation was indicated by the COD reduction resulting in effective reduction of turbidity.

Suspended solids for textile water from industry were ranged 15 mg/L – 19 mg/L. At 10 kGy and 100 kGy of gamma irradiation, the suspended solid was 16 mg/L and 2 mg/L respectively. Meanwhile at 10 kGy and 100 kGy of electron beam irradiation the value for suspended solid were 14 mg/L and 3 mg/L respectively (Fig. 4.). Suspended solids were decreased, as they were converted to precipitates resulting from the degradation of organic substances and suspended matter in wastewater [Compton, 1971].

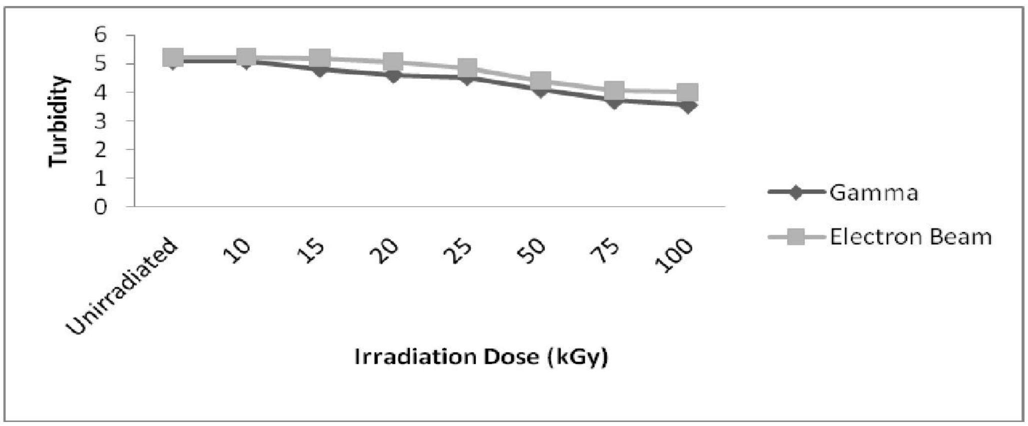

Fig. 3: Effect of irradiation dose on turbidity

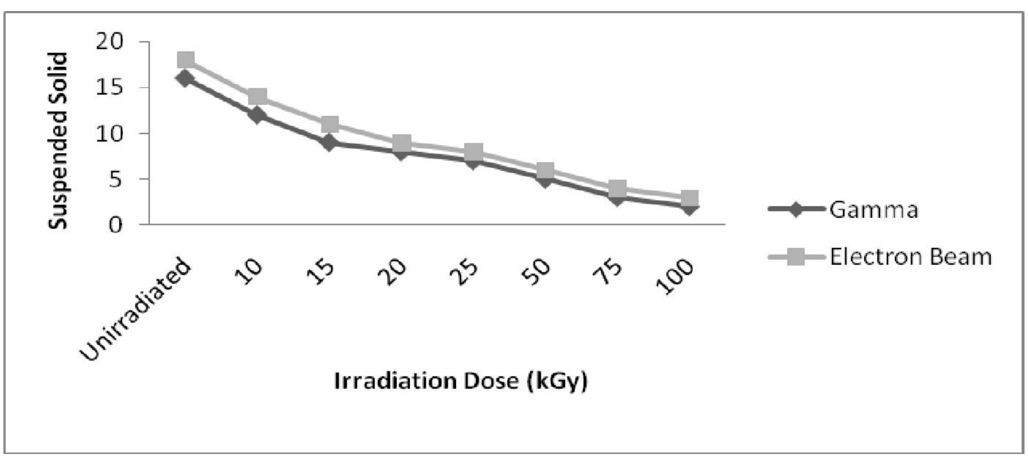

Fig. 4: Effect of irradiation dose on suspended solid

Effect of irradiation dose on BOD_5

Biochemical oxygen demand (BOD_5) is an analysis to determine the uptake rate of dissolved oxygen by the biological organisms in a body of water (www.wikipedia.com). Before irradiation, the BOD_5 value for the wastewater ranged 76 - 78 mg/L. At 10 kGy and 100 kGy of gamma irradiation, the BOD_5 was recorded at 61 mg/L and 38 mg/L. BOD_5 value at 2 kGy of electron beam irradiation was 69 mg/L and at 100 kGy BOD_5 was 44 mg/L. The BOD_5 results for both types of ionizing irradiation are shown in Fig. 5. BOD_5 measures the oxygen utilized mainly for biochemical degradation of organic material. High BOD_5 value can be interpreted as high concentration of oxidizable materials present in a water sample. Therefore the reduction of BOD_5 implies that oxidizable materials found in the sample have been reduced. This reduction can be expected and is in agreement with the results obtained for COD as mentioned above. The reduction of oxidizable materials was due to complete decomposition of organic pollutants found by ionizing radiation [Tchobanoglous et al., 1985].

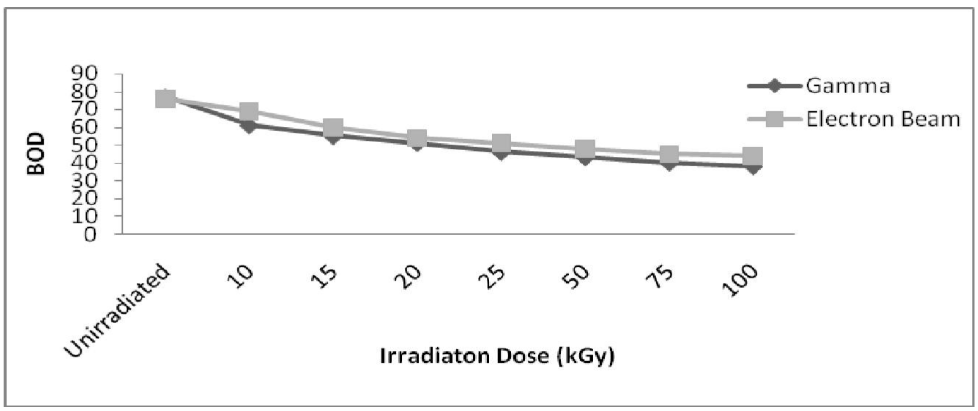

Fig. 5: Effect of irradiation dose on BOD

CONCLUSION

Irradiation by gamma and electron beam aims to destroy the organic pollutants present in textile industry wastewater. It was found that the dose has contributed substantially to the removal of organic pollutants. At initial raw concentration of 400 mg/l COD, all the properties, pH, COD, BOD, turbidity and suspended solid shows reduction after irradiation especially at a high dose. Gamma irradiation is more effective in terms of removal of organic pollutants than electron beam. This may be due to its short wavelength, high energy and very high penetration compared to electron beam. However, electron beam is more effective pertaining to cost and time consumption. Thus, electron beam irradiation is more suitable to be introduced to the industries. For more effective results, electron beam irradiation can be combined with conventional treatment method such as biological treatment.

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