EFFECT OF GAMMA IRRADIATION ON TEXTILE WASTE WATER

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ABSTRACT

This paper studies the use of gamma irradiation for textile waste water treatment. Prior to irradiation, the raw wastewa ter was diluted using tap water to targeted concentration of COD 400 mg/l. The sample was irradiated at selected dose between the ranges of 2kGy to 100kGy. The results showed that Irradiation was effective in removing the highly colored refractory organic pollutants. The COD removal at lowest dose, 2kGy is about 310 mg/l. Meanwhile, at highest dose, 1 00kGy the COD reduced to 100mg/l. The degree of removal influenced by the dose introduced during the treatment pro cess. As the dose increased, higher removal of organic pollutant was recorded. On the other hand, other properties of t he wastewater such as pH, turbidity, suspended solid, BOD and color shows tremendous changes as the dose increases. This shows the concentration of pollutants and dose of irradiation applied are directly proportional to each other.

ABSTRAK

Kertas kerja ini membincangkan tentang penggunaan teknik penyinaran gamma untuk merawat air sisa buangan tekstil . Sebelum proses penyinaran dilakukan, sampel air buangan dicairkan dengan menggunakan air paip untuk mendapatk an kepekatan COD 400mg/l yang disasarkan. Sampel kemudiannya disinarkan pada dos yang dipilih diantara 2kGy hin gga 100kGy. Hasil kajian menunjukkan bahawa teknik penyinaran gamma berkesan dalam menyingkirkan bahan pence mar organik refraktori yang tinggi keamatan warnanya. Pada dos penyinaran terendah iaitu 2kGy nilai penyisihan CO D adalah 310mg/l. Manakala pada dos penyinaran tertinggi iaitu 100kGy nilai COD berkurang menjadi 100mg/l. Hasil daripada kajian, mendapati bahawa penyingkiran bahan pencemar ini dipengaruhi oleh dos penyinaran yang digunaka n semasa proses rawatan. Peratus penyingkiran bahan pencemar meningkat apabila dos penyinaran meningkat. Kajian keatas pH, kekeruhan, jumlah pepejal termendak, BOD dan warna sampel air menunjukkan perubahan yang baik deng an meningkatnya nilai dos penyinaran. Ini menunjukkan kepekatan bahan pencemar dan dos penyinaran berkadar lang sung antara satu sama lain.

Keywords: Wastewater, Gamma Irradiation, COD, BOD, Turbidity

INTRODUCTION

The growth of Malaysia's textiles and apparel industry accelerated in the early 1970s when the country embarked on export-oriented industrialization. With exports valued at RM 10.49 while imports amounted to RM 5.46 billion thus making Malaysia a net exporter of textiles and textile products. There are 662 licensed companies in production with investments of RM8.3 billion. The industry employs more than 68,264 workers (www.mida.gov.my).

The textile industry is very water intensive. Water is used for cleaning the raw material and for many flushing steps during the whole production. Produced waste water has to be cleaned from fat, oil, wax, heavy metal, surfactant, suspended solid, dyes and other chemicals, which are used during the several production steps. If this waste water released to stream, without proper treatment, could yield great impact on environment (Ahmad *et al.*, 2002).

The cleaning process is depending on the kind of waste water being produced which based on production and also on the amount of used water. Water treatment with different kind of pollutants, is large-scale, because of the many cleaning and removing steps involved. This refractory organic pollutants are hardly biodegradable and their removal using physical treatment, chemical treatment and biological treatment alone usually not very effective. Low biodegradability of textile waste water usually confines biological treatment and other conventional methods as well (Ting & Jamaludin, 2008)

Existing conventional treatment using physical and chemical treatment is not capable to destroy or decompose the recalcitrant and toxic organic pollutants but rather transfer the pollutants from liquid medium to solid medium via coagulation/chemical process. Further more conventional treatment using physical and chemical treatment process consumes substantial amount of chemical that will increase the amount of sludge generated. The sludge need to be treated. Thus, radiation technology has been identified as efficient method to treat highly colored refractory organic wastewater.

Han, B., *et al.* (2002) reported the use of electron beam treatment of waste water that leads to their purification from various pollutants. This is caused by decomposition of organic pollutants as a result of their reactions with highly reactive species formed from water hydrolysis.

This paper studies decomposition of aggregate organic pollutants in textile wastewater by using gamma irradiation. Gamma irradiation, also known as gamma rays (denoted as γ), is electromagnetic radiation of high frequency which produced by sub-atomic particle interactions. Gamma-rays have the smallest wavelengths and the most energy of any other wave in the electromagnetic spectrum (Fang & Wu, 1999). The effects of gamma radiation on textile wastewater at different doses applied to destroy organic pollutants were investigated and explained.

METHODOLOGY

Sampling and sample preparation

Wastewater used in this research was from textile industries which located at Rawang Integrated Industrial Park (RIIP), Malaysia and was stored in refrigerator at 4^0C. The sample was collected from several processes such as washing, dying, waxing and rinsing. The content of wastewater was unknown specifically for each individual pollutant and been classified as mixture of various chemicals. Prior to irradiation, the sample was diluted to targeted concentration of COD at 400 mg/l for same conditional starting point. Initial concentration was same for the all sample which be radiated at different doses as the aid of comparative studies.

Irradiation

The irradiation was conducted at room temperature using Gamma radiation. The characteristics of wastewater before irradiations are shown in Table 1. Experiment carried out by fill in the sample into 500ml glass bottle. Selected doses for this study are 2 kGy, 4 kGy, 5 kGy, 6 kGy, 8 kGy, 10 kGy, 12 kGy, 15 kGy, 20 kGy, 25 kGy, 50 kGy, 75 kGy and 100 kGy.

Sample bottles were placed on aluminum totes which automatically enter and leave radiation room on roller conveyor system. Totes are conveyed on two levels, lower and upper levels, around Colbalt-60 source using a two-pass system. This provides maximum utilization of the ionizing energy ensuring that samples are well exposed on all sides.

Sample analysis

Samples were analyzed before and after irradiation. COD is equivalent to the amount of oxygen required to chemically oxidize the organic matter contained in wastewater. To determine the COD sample was first digested using dichromate (HR range plus) in Hach reactor and COD value was determine by Hach-2400 spectrophotometer. BOD measures the rate of oxygen uptake by micro-organism in a sample of wastewater and was measured at temperature 20^0C over an elapsed period of five days in the dark. It is not precise quantitative test, but used widely as an indicator to measure water quality. Absorbance was carried out using Shimadzu Spectrophotometer at wavelength of 300-680nm. pH of the sample was analyzed using pH meter (WTW Multi 340i).

Table 1: Characteristic of raw textile wastewater

Parameters	Values
pH	10.25-10.35
COD	3000mg/l
Color	dark purple
Turbidity	69.8
Suspended solid	17.9mg/l

RESULTS AND DISCUSSIONS

Effects of irradiation dose to pH

The pH of raw textile wastewater which was collected from industry was ranged from 10.25 to 10.35. Anyhow, after irradiation the pH was reduced. The lowest pH was recorded at highest dosage as shown in (Fig. 1). At 100kGy of irradiation dose the pH was 9.9. These results indicate that after irradiation the big dye molecules were broken down to smaller organic compounds with organic acids such as dicarboxylic acids or acetic acid as the byproducts (Vinogdopal et al, 1998; Wang et al, 2006). The presence of these acids reduces the pH of the waste water.

Effects of irradiation dose in removal of COD

COD determine 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. The COD value for textile wastewater was dropped as the dose increased. At highest dose, the lowest COD value obtained (Fig. 2). At lowest dose, 2kGy the COD was 390 mg/L but at 100kGy the COD recorded was 125 kGy. When water exposed to ionizing irradiation, the water molecule will undergo 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, which formed from the pollutants causes the removal of pollutant from the wastewater (Buxton et al, 1998; Geoff, 2002).

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:

$$H_2O^+ + HO_2 \longrightarrow H_3O^+ + \bullet OH$$

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

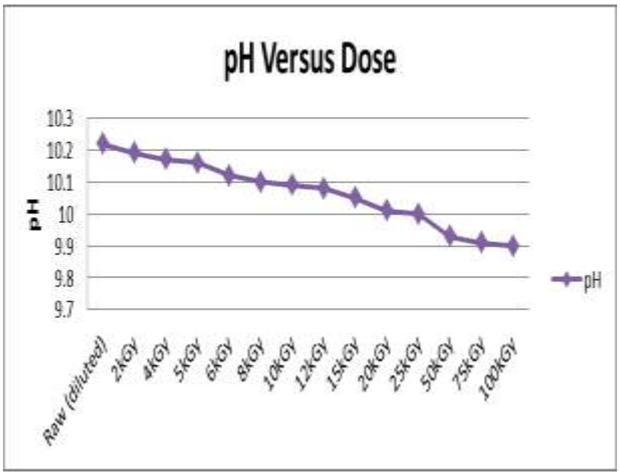

Figure 1: Graph pH versus Irradiation Dose

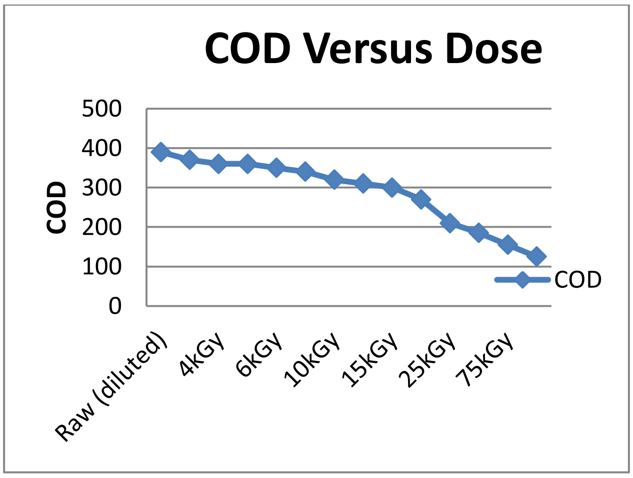

Figure 2: Graph COD versus Irradiation Dose

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 & Neta, 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 decomposed at higher absorbed dose.

Effects of irradiation dose on turbidity and suspended solid

Turbidity is the cloudiness of a liquid caused by individual particles (suspended solid). Turbidity of raw textile wastewater was 5.09 NTU. There was increase in turbidity when the textile waste water was irradiated. At 2kGy the turbidity was 6.95 NTU. But as the dose increases, the turbidity of the water decreases. At highest dose the turbidity was 4.27 NTU (Fig. 3). The increase in turbidity due to dissolved organic pollutants in the wastewater but as the dose increases the organic pollutants being decomposed by irradiation energy (Al-Ani et al, 2006). Thus, reduction in turbidity was observed.

The same trend was found for suspended solid as well. Suspended solid for raw textile water was 6 mg/L. At 2kGy it goes up to 16 mg/L. But at 100 kGy it reduced to 3 mg/L (Fig. 4). Suspended material which are large and heavy enough, will settle rapidly to the bottom of the container if a liquid sample is left to stand (the settable solids), very small particles will settle only very slowly which cause the liquid to appear turbid and causes both turbidity and suspended solid to be high (www.wikipedia.com). Suspended solid were decreased, as they were converted to precipitates resulting from the degradation of organic substances and suspended matter in wastewater.

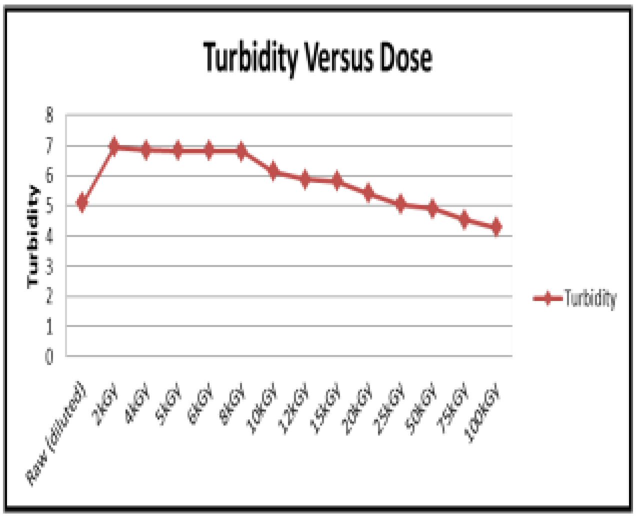

Figure 3: Graph Turbidity versus Irradiation Dose

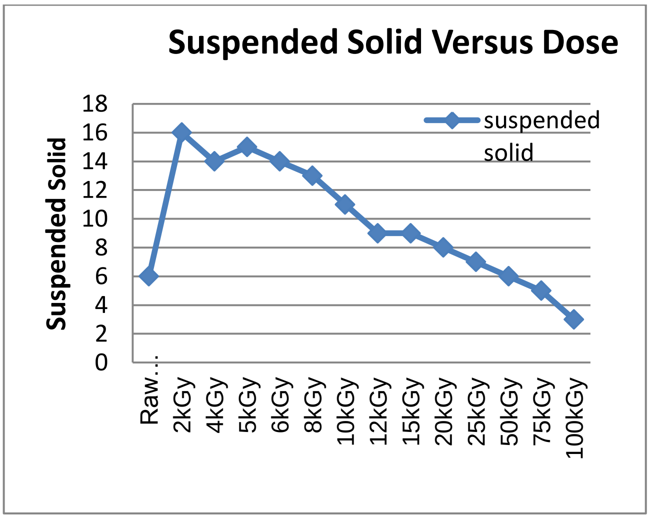

Figure 4: Graph Suspended Solid versus Irradiation Dose

Effects of irradiation dose on BOD

Biochemical oxygen demand (BOD) is a chemical procedure for determining the uptake rate of dissolved oxygen by the biological organisms in a body of water (www.wikipedia.com). Initially before irradiation the BOD value for the waste was 77 mg/L. After irradiation reduction was observed in BOD value. As the dose increases, the BOD value decreases. At 2 kGy BOD was 76 mg/L and at 100 kGy BOD dropped to 40 mg/L (Fig. 5). The decreased resulted from the destruction of microorganisms responsible for oxygen consumption. It is known as microorganisms are very sensitive to radiation pulses. In addition, the radiation energy can degrade organic compounds found in biological systems of waste (Mytleka, 1971).

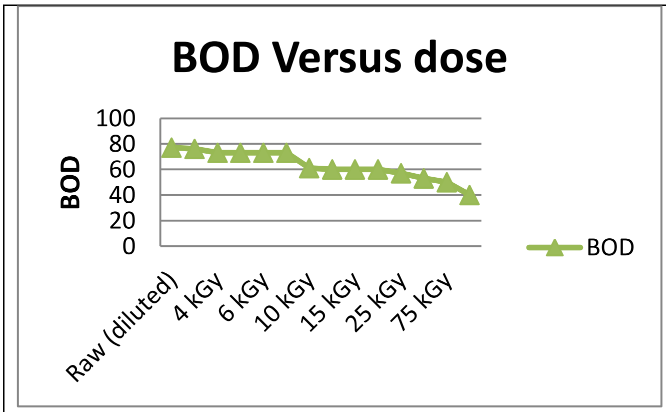

Figure 5: Graph BOD versus Irradiation Dose

CONCLUSION

Irradiation by Gamma radiation is a quite efficient way to destroy the organic pollutants present in textile industry wastewater. The dose contributed substantially to the removal of organic pollutants. All the properties, pH, COD, BOD, turbidity and suspended solid shows significant reduction after irradiation especially at high dose. This proved that, gamma radiation is capable to destruct refractory organic pollutants which found in textile wastewater.

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REFERENCES

Ahmad, A.L., Harris, W.A. and Seng, O.B. 2002. Removal of dyes from wastewater of textile industry using membrane technology. Journal Technology. 36, 31-44.

Anbar, M., Neta, P. Radiation chemical destruction of phenol in oxygenated aqueous solutions, Int. 5. appl. Radiat. Tsot., 1967, Vol.18, Pp 493

Buxton, G.V., Greenstock, C.L., Helman, W.P., and Ross, A.B. 1998. Critical rewiew of rate constants for reactions of hydrated electrons, hydrogen atom and hydroxyl radicals ($^{\cdot}OH/^{\cdot}O^{-}$) in aqueous solutions. Journal of Physical Chemical References Data 17:513-886.

Fang, X., Wu, J., 1999. Some remark on applying radiation technology combined with other methods to the treatment of industrial wastes. Radiat. Phys. Chem. 55 (4), 465-468.

Getoff, N. 2002. Factors influencing the efficiency of radiation-induced degradation of water pollutants. Radiation Physics and Chemistry 65:437-446.

Han, B., Ko, J., Kim, J., kim, Y., Chung, W., I.E Makarov, A.V Ponomarev, A.K Pikaev.2002,Combine electron-beam and biological treatment of dyeing complex wastewater. Pilot plant experiments, Radiation Physics and Chemistry., 64, 53-59.

Al-Ani, M.Y & F. R. Al-Khalidy.(2006) Use of Ionizing radiation technology for treating municipal waste water. Int. J. Environ. Res. Public Health, 3(4), 360-368.

Mytleka, A. I. Radiation treatment of industrial wastewater an economic analysis, Isot. Radiati. Technol., 1971, Vol. 84, Pp 444.

http://en.wikipedia.org/wiki/BOD

http://en.wikipedia.org/wiki/Turbidity

http://www.mida.gov.my/en_v2/index.php?page=textiles-and-apparel-industry

Ting & Jamaludin, 2008. Decolorization and decomposition of organic pollutant for reactive and dispersive dyes using electron beam technology :Effect of the concentrations of pollutants and irradiation dose. Radiat. Phys. Chem. 73, 76-80.

Vinogdopal, K., Peller, J., Makogon, O., Kamat, P., 1998. Ultrasonic mineralization of a reactive textile azo dye, Remazol Black B. Water Res. 32, 3646-3650.

Wang, M., Yang, R.Y., W.F., Shen, Z.Q., Bian, S.W., Zhu, Z.Y., 2006. Radiation-induced decomposition and decolorization of reactive dyes in the presence of H_2O_2. Radiat. Phys. Chem. 75, 286-291.