Evaluation on Ecological Stability and Biodegradation of Dyeing Wastewater pre-Treated by Electron Beam

M.J.Lee[1)], C.K.Park[1)], D.H.Yoo[1)], J.K.Lee[1)], B.J.Lee[1)], B.S.Han[2)], J.K.Kim[2)], Y.R.Kim[2)], S.J.Ahn[3)], J.S.Choi[3)]

[1)] Korea Atomic Energy Research Institute
[2)] EB-Tech. Co. Ltd
[3)] Dye-Tech. Korea

Email contact of main author: mjlee@kaeri.re.kr

Abstract. Biological treatment of dyeing wastewater irradiated by electron beam has been performed in order to evaluate the biodegradation and the toxicity of effluent on ecological stability. Two samples, which one is irradiated dyeing wastewater and other is unirradiated dyeing wastewater were compared, respectively. Electron accelerator of 1 MeV, 40kW with the dose of 1.0 kGy was applied. Daphnia magna was cultivated for determine the toxicity. The biodegradability by irradiation was increased. The effectiveness of irradiation was remarkable when shorter HRT was applied to biological treatment process. The activity of microorganisms by irradiation was more active comparing with the biological treatment process without irradiation. The toxicity on the Daphnia magna of effluent was decreased from 2.49 to 2.16 when a dyeing wastewater was pre-treated by electron beam irradiation.

1. Introduction

Biological treatment of dyeing wastewater pre-treated by electron beam irradiation has been performed in order to evaluate the biodegradation and the toxicity of effluent on ecological stability. In the process of electron-beam treatment of wastewater there are utilized chemical transformations of pollutants induced by ionizing radiation. Partial decomposition of pollutant takes place as well as transformations of pollutant molecules that result in improving subsequent purification stages like as biological processing. Dyeing wastewater contains many kind of pollutants which are difficult to be decomposed completely by microorganisms. In this study, biodegradation with dyeing wastewater pre-treated by electron beams was observed. In the other hand, consideration on public acceptance in terms of ecological stability of biological effluent pre-treated by electron beams was given.

2. Experimental

2.1. Experimental procedure

FIG.1 shows the experimental procedure. Two samples are prepared. One is irradiated dyeing wastewater and other is unirradiated dyeing wastewater. These two samples are measured by BOD_5 and CODcr in order to determine biodegradability. Samples are introduced to the biological oxidation reactor and they are oxidized with different HRT. After oxidation they are discharged and measured by toxicity in order to compare ecological stability.

2.2. Electron beam irradiation

Electron accelerator(EB-Tech) of 1 MeV, 40kWwith the dose of 1.0 kGy was applied. The dyeing wastewater is placed in storage vessel, which serves as saturator-equalizer. Dyeing

wastewater from the vessel was moved with controlled consumption by pump to jet nozzle (FIG.2). Diameter of jet was equal to the range of 1 MeV electrons in water. The dyeing wastewater injected directed in horizontal plane; their flight length was equal to ~1.5 m (at the initial rate 3m/s). The dyeing wastewater injected along horizontal part of their flight was treated by electron beam. Then irradiated dyeing wastewater was collected into the container in order to be treated by subsequent biological process.

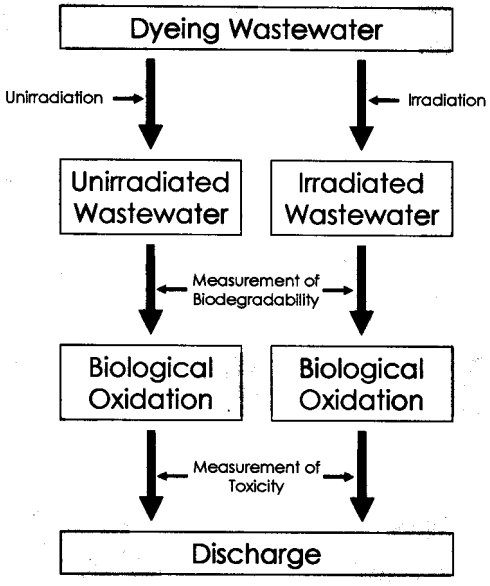

FIG.1. Experimental procedure

FIG.2. A view of irradiation of dyeing wastewater

2.3. Biodegradability

Two kind of tests were carried out for determine the biodegradability of dyeing wastewater. Two samples of 50 ml with and without irradiation were measured by CODcr and BOD_5, respectively and ratio of BOD_5/CODcr was compared. On the other hand, BOD removal efficiency was compared with irradiated and unirradiated sample under operation of biological oxidation process.

2.4. Biological oxidation process

Four simple type of standard activated sludge reactors with dimention (205w x 265h x 100w) were applied for carry out biological oxidation (FIG.3). Irradiated and unirradiated dyeing

wastewater were treated in the biological oxidation reactor according to fixed hydraulic retention time (HRT) with 24hr, 30hr, 36hr and 48hr, respectively. Effluent was analyzed in terms of degree of biodegradation, BOD_5, COD_{Mn}, CODcr, T-N and T-P.

FIG.3. Reactor used for biological treatment of dyeing wastewater irradiated

2.5. Ecological stability of effluent

Samples obtained from sedimentation zone of biological reactor were diluted according to experimental design. Daphina magna was cultivated and stored in the incubator before using (FIG.4). Five samples with control and different dilution factors were prepared for different HRT. Counting on survival number of Daphina magna was performed after 24 hours for samples with different HRT, respectively (FIG.5).

FIG.4. Daphina magna used in Ecological stability test

FIG.5. Counting of survived daphnia magna

3. Results

3.1. Biodegradability

The biodegradability of the dyeing wastewater irradiated was increased to higher 0.1-0.3(FIG.6) , and the BOD removal efficiency of a biological treatment process was also improved and stabilized when dose of 1 kGy was applied regardless of HRT while BOD removal efficiency of unirradiated dyeing wastewater with HRT of 18 hrs was decreased suddenly as shown in FIG.7. The improvement of biodegradability was assumed by transformation of high molecule compounds into low molecule compounds by irradiation and it was confirmed by detection of the organic acids by using HPLC shown in FIG.8. It showed that low molecule organic acid was produced in accordance with irradiation. Relatively low molecule organic acid can be easily oxidized by microorganisms.

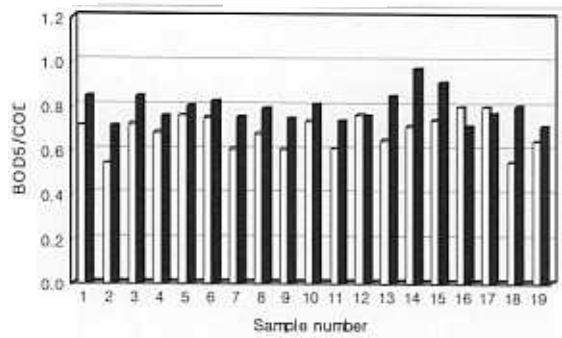

FIG.6. Comparison of biodegradability based on BOD_5/COD for dyeing wastewater by irradiation (□ 0 kGy, ■ 1 kGy)

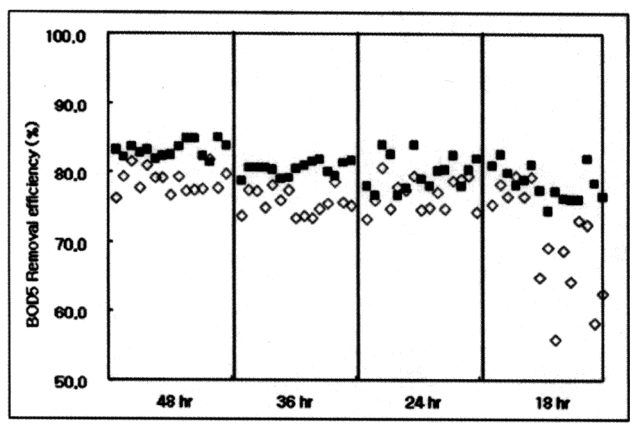

FIG.7. BOD_5 Removal efficiency in accordance with irradiation and HRT (◇ 0 kGy, ■ 1 kGy)

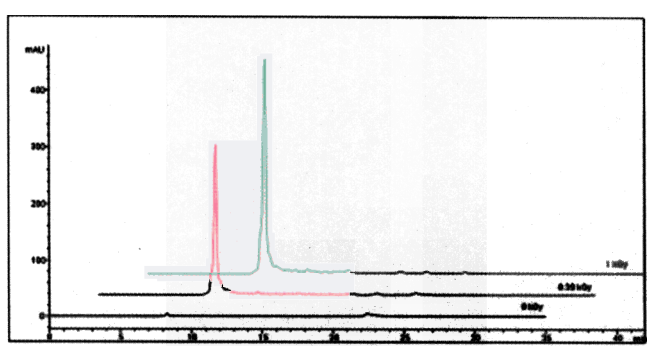

FIG.8. Appearance of low molecule organic acid peak in according to irradiation dose

3.2. COD load

When longer HRT was applied to a biological treatment process, the difference from treatment efficiencies between an only biological treatment process and a biological treatment process connected with an irradiation was neglectable. However, the effectiveness of irradiation was remarkable when shorter HRT was applied to biological treatment process(FIG.9).

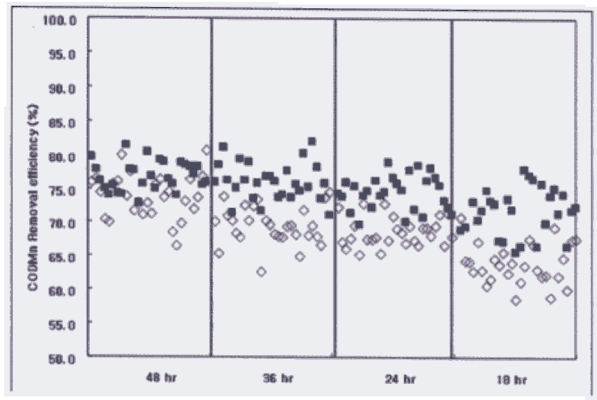

FIG.9. COD_{Mn} Removal efficiency according to irradiation and HRT (◇ 0 kGy, ■ 1 kGy)

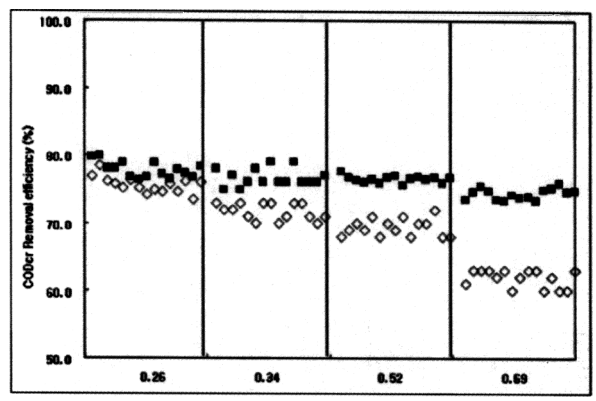

FIG.10. CODcr removal efficiency according to F/M ratio (◇ 0 kGy, ■ 1 kGy)

The treatment effectiveness of a biological treatment process connected with an electron beam irradiation was higher than that of only biological treatment process when F/M ratio was applied about 0.68 to biological treatment processes (FIG.10). Considering that the F/M ratio of a standard activated sludge process is about 0.25, the biological treatment process connected with electron beam irradiation looks more effective when F/M ratio is increased.

3.3. Activity of microorganisms

The activity of microorganisms in the dyeing wastewater treated by electron beam was more active comparing with the biological treatment process without irradiation. The appearance of *vorticella* in the biological reactor means that biological reactor is well operated. As shown in FIG.11, large number of *vorticella* could be observed in the biological reactor connected with irradiation. The reason can be explained by the change of DHA (Dehydrogenase activity) by INT(2-(p-iodophenyl)-3-(p-notrophenyl)-5-phenyltetrazolium chloride) in the biological reactor in according to time at HRT 24. As shown in FIG.12, DHA by INT in the biological reactor connected with irradiation was not decreased while it was slowly decrease according to time in the biological reactor without irradiation. This means that activity of microorganisms becomes more weaken.

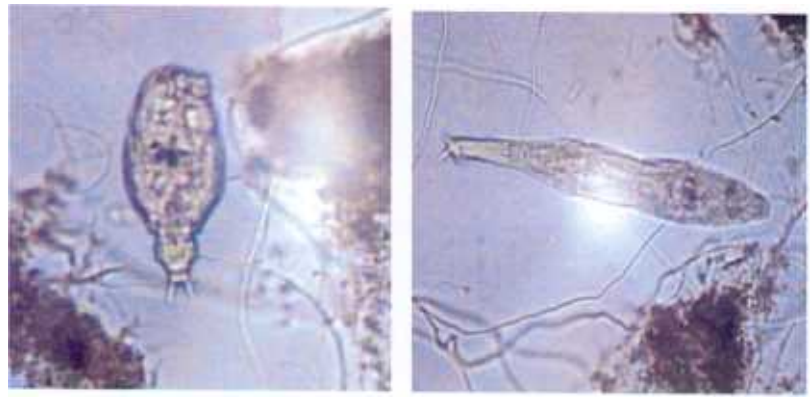

FIG.11. Vorticella observed from biological treatment reactor connected with irradiation and high F/M ratio

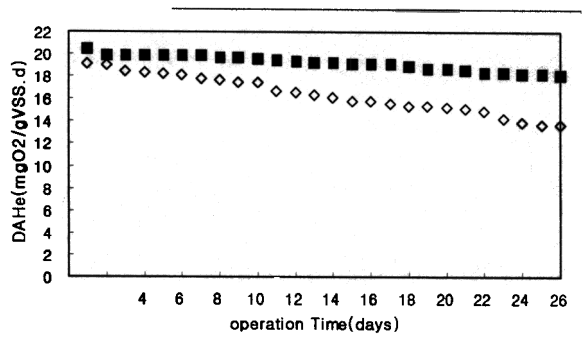

FIG.12. The change of DHA (Dehydrogenase activity) by INT in the biological reactor at HRT 24(◇ 0 kGy, ■ 1 kGy)

3.4. Toxicity

The toxicity on the Daphnia magna of wastewater was decreased from 2.49 to 2.16 when a dyeing wastewater was treated by an electron beam irradiation. For mortality of raw dyeing wastewater irradiated samples itself recorded low value except for only 50% of concentration, and it showed same trend with longer HRT. In case that an electron beam irradiation was not applied, the effluent from biological treatment with HRT of 18hr was toxic to the Daphnia magna. However, the effluent from a biological treatment connected with an electron beam irradiation was not toxic regardless of HRT.

TABLE I. List of toxicity on effluent from biological oxidation process of irradiated and unirradiated dyeing wastewater by electron beam

Reaction condition / Analysis condition		EBX RW	EBO RW	18Hr EBX	18Hr EBO	24Hr EBX	24Hr EBO	36Hr EBX	36Hr EBO	48Hr EBX	48Hr EBO
Concentration (%)	Number Exposed	Mortalities		Mortalities		Mortalities		Mortalities		Mortalities	
100%	20	20	20	10	0	2	0	2	1	2	0
50%	20	7	11	2	0	0	0	0	0	1	0
25%	20	5	1	0	0	0	0	0	0	0	0
12.5%	20	4	0	0	0	0	0	0	0	0	0
0%	20	0	0	0	0	0	0	0	0	0	0
EC_{50}(%)		40.16	46.27	99.16	>100	>100	>100	>100	>100	>100	>100
Toxic Unit		2.49	2.16	1.01	<1	<1	<1	<1	<1	<1	<1

1) EBX RW : Unirradiated dyeing wastewater
2) EBO RW : Irradiated dyeing wastewater

4. Conclusions

The results of laboratory investigations on biodegradation and ecological stability of effluent showed that biodegradation of dyeing wastewater pre-treated by electron beam was enhanced compared to unirradiated one. In the initial stage of biological oxidation regardless of different HRT, dye wastewater pre-treated by electron beam could be oxidized easily compare to without treated one. More number of survived daphnia magna could be observed in the biological effluent pre-treated by electron beam. This means that biological effluent pre-treated by electron beam can be said " it is safe on the ecological system".

Reference

[1] Bum-Soo Han, et al., " Electron beam treatment of dyeing wastewater" International Symposium on Radiation Technology in Emerging Industrial Application, Beijing, China (2002)

[2] Sang-Jun An, et al., " Removal of dye wastewater color by electron beam" Korea Society of Environmental Engineering, Proceedings ,2003