

## Decomposition characteristics of acetaldehyde using advanced oxidation technology

Youn-Suk Son

Dept. of Advanced Technology Fusion  
Konkuk University  
Seoul, Korea  
alkein01@konkuk.ac.kr

Jo-Chun Kim

Dept. of Environmental Engineering  
Konkuk University  
Seoul, Korea  
jckim@konkuk.ac.kr

Jang Seung Choi, Sang-Hun Lee, Jun Hyung Park

Dept. of Eco friendly Research  
Korea Dyeing Technology Center  
Daegu, Korea  
jschoi@dyetec.or.kr

**Abstract**—In this work, decomposition characteristics of acetaldehyde ( $\text{CH}_3\text{CHO}$ ) were investigated with respect to various factors, such as initial concentration, absorbed dose, and background gas using advanced oxidation technology. Absorbed doses were adjusted from 2.5 to 10 kGy. We demonstrated that acetaldehyde removal efficiencies tended to increase as absorbed dose increased and initial concentration decreased. Carbon monoxide, carbon dioxide, and some trace compounds were produced by radiolysis of acetaldehyde.

**Keywords**—component; advanced oxidation technology; acetaldehyde; absorbed dose; electron beam, OH radical

### I. INTRODUCTION

Volatile organic compounds (VOCs) are emitted into the atmosphere from a variety of industrial processes [1]. Acetaldehyde is well known as causing a deterioration of the organ of smell, vomit, pain in the chest, sore throat and difficulty in breathing [2]. Furthermore, it is classified as a matter of carcinogen possibility by USEPA. Besides, acetaldehyde may contribute to the formation of photochemical oxidants such as  $\text{O}_3$  and PAN [3, 4].

At this time, common technologies such as adsorption, filtration, and combustion have some troubles like low efficiency, high maintenance cost; therefore, more cost effective technologies for VOCs control are needed [5, 6, 7]. Recently, to resolve these issues, electron beam method has been applied to high flow rate and low concentration of emission facilities at ambient air temperature since it requires relatively low energy [8].

In this work, removal characteristics of acetaldehyde ( $\text{CH}_3\text{CHO}$ ) were investigated at different background gases (oxygen, nitrogen, and helium), initial concentrations, and absorbed doses (kGy) using electron beam irradiation. Besides, by-products formed in the decomposition process of acetaldehyde were identified.

### II. EXPERIMENTAL METHOD

#### A. Electron beam irradiation

In this work, a 1 MeV electron beam accelerator (maximum power 40 kW, ELV-4 type, Korea Dyeing Technology Center, Korea) was used. The average absorbed dose was measured using cellulose triacetate (CTA) film dosimeter (FTR=125, Fuji, Japan). The irradiated films were analyzed by UV-visible spectrophotometer (UV-160A, Shimadzu, Japan) at 280 nm within 2 h. Absorbed doses were adjusted as 2.5, 5, 7.5, and 10 kGy during the experiment to examine the decomposition efficiency of acetaldehyde.

#### B. Mixing/flow system

The entire experimental process was conducted with batch and continuous flow systems. Acetaldehyde samples were prepared to concentrations from 500 to 200 ppm. A batch system consisted of 1 L Tedlar (SKC, USA) reactor and background gases, such as  $\text{O}_2$ ,  $\text{N}_2$ , and He. On the other hand, the continuous flow system consists of zero air system, VOC generator, reactor and sampling port. Air flow was introduced into the control system with 15L/min of zero air flow. A more detailed explanation of these systems can be found elsewhere [8, 9].

#### C. Analytical method

LC-MS/MS (Agilent 1200 series, USA) was used to conduct the quantitative analysis on acetaldehyde, where an LC column (C18 reversed phase) was used. A  $\text{CO}/\text{CO}_2$  analyzer (Gas data PAQ, GAS data Ltd, UK) was also used to measure CO and  $\text{CO}_2$  produced by the oxidation of hydrocarbons. An  $\text{O}_3$  Analyzer (Model 49C, Thermo, USA) was used to observe the amount of ozone produced due to the radical reaction of oxygen during electron beam radiation.

### III. RESULTS AND DISCUSSION

#### A. Effect of background gases

In general, primary electrons produced by the electron beam accelerator were absorbed into the background gases to ionize the air, making the  $N_2$ ,  $O_2$ , and  $H_2O$  in the background gases go through excitation processes to form radicals, ions, and secondary electrons [9]. Accordingly,  $O_2$  and  $N_2$  were selected as target background gases to examine the decomposition characteristics of the produced radicals in this work. Figure 1 shows the removal efficiencies of the electron beam under three different background gases. Acetaldehyde removal efficiencies tended to increase as absorbed doses increased. The maximum removal efficiencies of the compound were above 90 % with two background gases ( $O_2$  and  $N_2$ ) at 10 kGy. However, the efficiency with Helium background at 10 kGy was below 40 %, which was relatively low compared to that with other background gases.

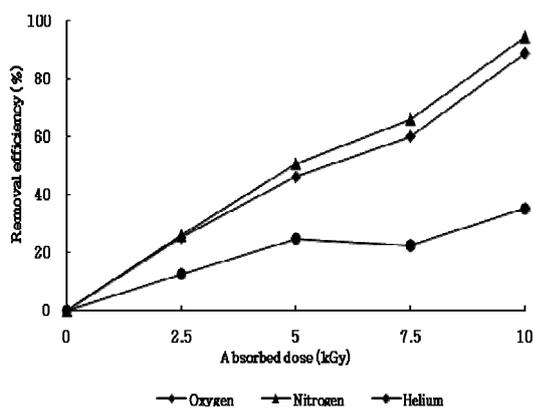


Figure 1. Decomposition efficiency of acetaldehyde by different background gases.

#### B. Removal efficiencies by various initial concentrations

In this study, electron beam irradiation was carried out to determine the decomposition efficiency of acetaldehyde with initial concentrations of 50, 100, and 200 ppm. Results are shown in Figure 2. In general, removal efficiency increased as the absorbed dose rose regardless of initial concentration.

For example, decomposition efficiency was 90 % at 200 ppm and 10 kGy. On the other hand, efficiency for 200 ppm acetaldehyde was 40 % at 5 kGy. Lower concentrations caused higher decomposition rates at lower absorbed doses, as shown in Figure 2.

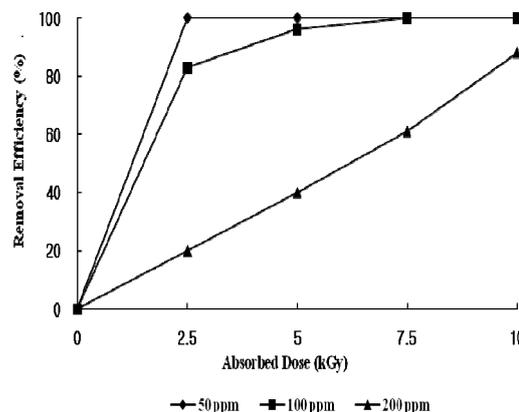


Figure 2. Removal efficiency of acetaldehyde by initial concentrations

#### C. By-products

VOC removal technique by electron beam takes advantage of advanced oxidation process. Accordingly, it is believed that CO and  $CO_2$  were produced when acetaldehyde was irradiated with electron beam. Concentrations of these by-products also increased as absorbed dose increased.

#### ACKNOWLEDGMENT

This work was supported by the Korea Ministry of Education as “The Second Stage of BK21 Project” and the Korean Ministry of Environment as part of “The Eco-Techtopia 21 Project”. This work was also supported by Hi Seoul Science (Humanities) Fellowship from Seoul Scholarship Foundation.

#### REFERENCES

- [1] Y. S. Son, K. J. Kim, and J. C. Kim, “A Review on VOCs control technology using electron beam,” *Asian Journal of Atmospheric Environment*, in press.
- [2] K. Gluch, J. Cytawa, and L. Michalak, “Electron impact ionization of acetaldehyde,” *International Journal of Mass Spectrometry*, vol. 273, 2008, pp. 20-23.
- [3] K. J. Kim, J. C. Kim, J. Kim, and Y. Sunwoo, “Development of hybrid technology using E-beam and catalyst for aromatic VOCs control,” *Radiation Physics and Chemistry*, vol. 73, 2005, pp. 85-90.
- [4] E.-C. Jeon, K. -J. Kim, J. -C. Kim, K. -H. Kim, S. -G. Chung, Y. Sunwoo, and Y. -K. Park, “Novel hybrid technology for VOC control using an electron beam and catalyst,” *Res. Chem. Intermed.* Vol. 34(8-9), 2008, pp. 863-870.
- [5] C. Wu, T. Hakoda, K. Hirota, and S. Hashimoto, “Effect of ionizing radiation on decomposition of xylene and benzene contained in air,” *J. Aerosols*, vol. 12 (2), 1997, pp. 115-123.
- [6] J. Likci, A. G. Chmielewski, E. Iller, Z. Zimek, J. Mazurek, and L. Sobolewski, “Electron-beam flue-gas treatment for multicomponent air-pollution control,” *Applied Energy*, vol. 75 (3-4), 2003, pp. 145-154.
- [7] H. Mätzing, K. Hirota, K. Woletz, H. R. Paur, “Product study of the electron beam induced degradation of volatile organic compounds (VOC),” *J. Aerosol. Sci.*, vol. 25 (1), 1994, S325-326.

- [8] J. C. Kim, Y. S. Son, K. J. Kim, Y. J. Lim, S. G. Chung, Y. Sunwoo, and M. Al-Sheikhly, "Combined radiolytic and catalytic oxidizing method to remove toluene in gas phase," *Radiation Physics and Chemistry*, vol. 79, 2010, pp. 797-802.
- [9] Son, Y. S., Park, K. N., Kim, J. C., 2010, Control factors and by-products during decomposition of butane in electron beam irradiation. *Radiation Physics and Chemistry*, in press.