Thai Environmental Engineering Journal Vol. 33 No. 2 (2019) : 27-32
www.eeat.or.th

# Kinetics of Ethyl Benzene Degradation in Biofilter using Isolated Bacteria from Petrochemical Wastewater Treatment Plant

**Patinya Sookpanya*, Sorn Suwannachot and Warawut Suadee**
Faculty of Science and Technology, Thammasat University, Pathum Thani 12121, Thailand
*E-mail : Patinya.sookpunya@gmail.com

## Abstract

The objective of this study was to investigate the kinetics of ethyl benzene degradation in the biofilter packed with the isolated bacteria from a petrochemical wastewater treatment plant. The inlet synthetic contaminated air containing 50 ppm ethyl benzene gas was introduced up flow in a 21.2 lite reactor with the flow rate of 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 5.0 L/min. The bacterias were fixed on plastic medias (polyethylene) 40 mm × 40 mm and packed in the reactor with about 30.0 cm height Both inlet and outlet ethyl benzene concentrations were measured using gas chromatography. The results were fit with the order of reaction equations. The relation between the concentrations and empty bed resident times (EBRT) show that the biofilter kinetics was Zero-Order Reaction Limited Model and The Kinetic constant ($k_0$) was 3.2192 ppm.min$^{-1}$. The kinetic of the biodegradation of the biofilter system may be described by an equation: $C_0$-C = (3.2192×t)-21.513.

**Keywords :** Biofiltration; Kinetic

## Introduction

Treatment of volatile organic compounds (VOCs) using a biofilter is one of the technique most widely used. This technique is effectively applied to control air pollution containing volatile organic compounds and/or inorganic compounds. Generally biofilter is a kind of treatment system that is easy to control and operate.

Ethyl benzene is the VOCs. It is highly flammable, clear colorless with an aromatic odor [1]. It is important used to an intermediate in the production of styrene in the petrochemical industry. For health effect, ethyl benzene is in 2B group (Possibly carcinogenic to humans) of IARC Monographs on the identification of carcinogenic hazards to human [2].

The degradation of volatile organic compounds in biofiltration involves many physical, chemical and microbiological phenomena [3]. Biofilter system design should consider factors to get an appropriate system and conditions to operate. One of the most important factors is the kinetic of the bacteria degradation. This characteristic is specific for each bacteria and conditions. Kinetics of degradation of bacteria in

the biofilter are classified into three forms 1) Zero-Order Reaction-Limited Model 2) Zero-Order Diffusion-Limited Model and 3) First-Order Model [1]. A studied kinetics of ethyl acetate and xylene in biofilter using sugarcane bagasse base as packing material. The inlet mixed gas (ethyl acetate and xylene) with the concentration of 0.2-1.2 g/$m^3$ were introduced to the system. The result found that the kinetic of the biofiltration was Zero-Order Diffusion Limitation Model [4]. The studied of kinetics and modeling of $H_2S$ in biofilter using cylindrical particle as medias and the empty bed resident time (EBRT) were controlled at 20, 30, 45 and 60 s. The result found that the kinetic of biofiltration was First-Order Model [5]. The studied of kinetics in biofilter using compost base as packing material. The $H_2S$ were passing with flowrate 68 l/min to the reactor, EBRT was 16 s. The result found that the kinetic of biofiltration was First order model for low concentration (<200 ppm) and Zero order model for high concentration (>400 ppm) [6]. The Studied of Kinetic in biofilter using compost mix with granular activated carbon media. The 3 parallel biofilter using compost mix granular activated carbon for 0, 3.55 and 13% by weight for each reactor. The BTEX inlet gas were introduced to the biofilter. The result found the kinetic was first order for BTEX concentration 50 ppm and Zero order for BTEX concentration range 235-440 ppm [7].

Biofilter system designed to degradation ethyl benzene using bacteria isolated from a petrochemical industry wastewater treatment plant. The group, which as bacteria *P. aeruginosa* S19 and *B. Cereus* O5-1/1 [8]. Therefore, the study of kinetics of bacteria degradation is needed in full scale design biofilter system.

## Materials and Methods

The study of kinetics ethyl benzene degradation in biofilter system used bacteria isolated from a petrochemical industry wastewater. Bacterias were fixed on plastic medias (polyethylene) 40 × 40 mm [9]. The surface area per unit volume of the media was 180 $m^2/m^3$. The medias were packed in a 21-liter reactor. Synthetic contaminant gas was generated by passing cleaned air over ethyl benzene surface in a closed glass impinger. The rich ethyl benzene gas was mixed with another cleaned air stream to control and vary the ethyl benzene concentrations. This synthetic ethyl benzene contaminated air with was introduce into the reactor at the flow rate of 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 5.0 L/min. Essential nutrient was also introduced into the reactor. The input ethyl benzene concentration was maintained about 50 ppm. Both inlet and outlet ethyl benzene concentrations were measured using gas chromatography (8900 GC-TID, Baseline-Mocon, Inc.). The schematic of the biofilter experimental system is shown in Figure 1.

This study aims to verify the kinetic of the biodegradation reaction of the system. The characteristic of the kinetics may be represented by three equations, (1) - (3), as following [4].

Zero-Order Reaction-Limited Model

$$C_0 - C = k_0 t \qquad \text{(Eq. 1)}$$

Zero-Order Diffusion-Limited Model

$$C = C_0 \left[ 1 - t \left( \frac{a k_0 D_e}{2 m C_0 \delta} \right)^{1/2} \right]^2 \qquad \text{(Eq. 2)}$$

Where $K_d$ is the rate coefficient of zero-order kinetic with diffusion limitation.

$$K_d = (ak_0D_e/2mC_0\delta)^{1/2}$$

First Order Model

$$\ln \frac{C}{C_0} = -k_1 t \qquad \text{(Eq. 3)}$$

Where C = Outlet concentration (ppm)

$C_0$ = Inlet concentration (ppm)

$k_0$ = Kinetic constant of Zero-Order Reaction Limited Model ($ppm.min^{-1}$)

$K_d$ = The rate coefficient of Zero-Order Kinetic with Diffusion Limited Model ($min^{-1}$)

$k_1$ = Kinetic constant of First-Order Model ($min^{-1}$)

t = Empty Bed Resident Times (min)

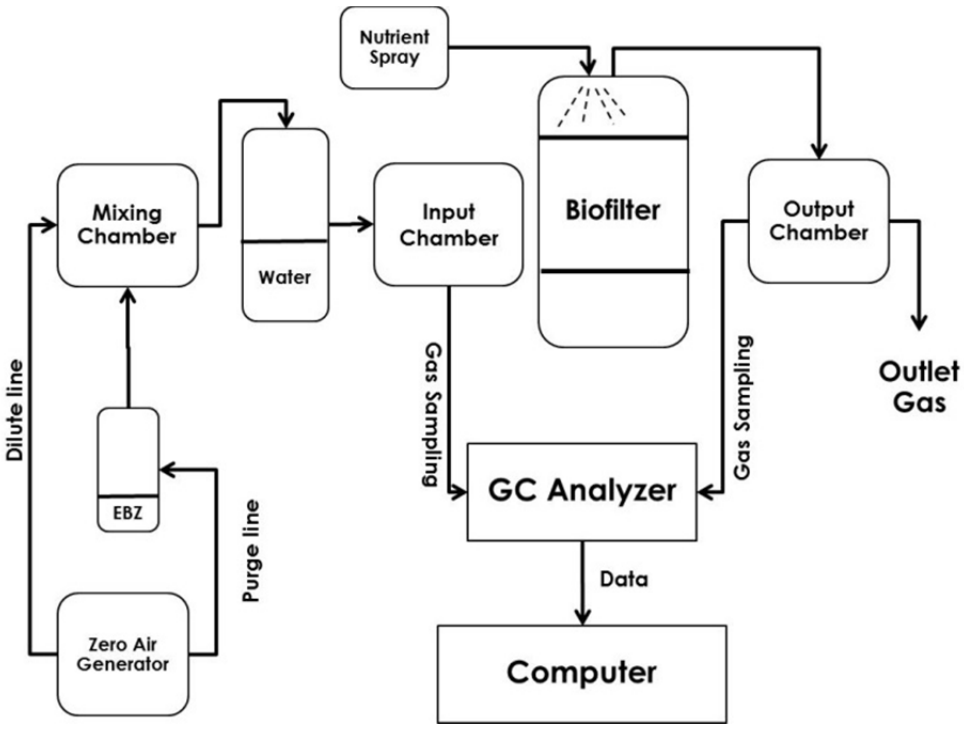


**Figure 1** Schematic of the biofilter experimental system

## Results and Discussions

The results of the study were exhibited as follows:

1. By plotting $C_0$-C with t as shown in Figure 2, the relation according to linear regression best fit was found 0.7965 for $R^2$. The Kinetic constant of the Zero-Order Reaction Limited Model was 3.2192 ppm.min$^{-1}$.

2. By plotting 1-$(C/C_0)^{(1/2)}$ with t as shown in Figure 3, the relation according to linear regression best fit was found 0.2744 for $R^2$. The rate coefficient of the Zero-Order Kinetic with Diffusion Limited Model was -0.0228 min$^{-1}$.

3. By plotting ln($C/C_0$) with t as shown in Figure 4, the relation according to linear regression was found 0.5547 for $R^2$. The Kinetic constant of the First-Order Model was 0.5695 min$^{-1}$

The result concluded that the kinetics reaction of ethyl benzene degradation in the biofilter reactor was Zero-Order Reaction Limited Model (Highest $R^2$). This result indicated that the bacteria degradation ethyl benzene was the limited function of the reaction more than the diffusion rate of ethyl benzene from the gas phase into the biofilm layer. The efficiency of the system depends on the abilities to degrade the ethyl benzene. The rate of reaction wasn't depending on the inlet concentration. The inlet concentration of ethyl benzene increased the reaction rate was stable. The kinetic of the biodegradation of the biofilter system may be described by an equation: $C_0$-C = (3.2192xt) - 21.513. This equation can be applied for sizing the Empty Bed Resident Times (EBRT) of a biofilter reactor and also to predict the efficiency of the biofilter system.

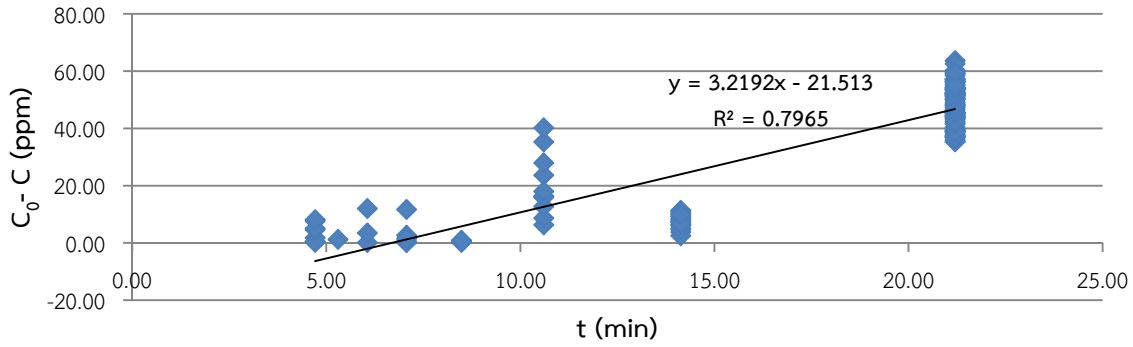


**Figure 2** Zero-Order Kinetic with Reaction Limited Model by shown plotting $C_0$-C with t

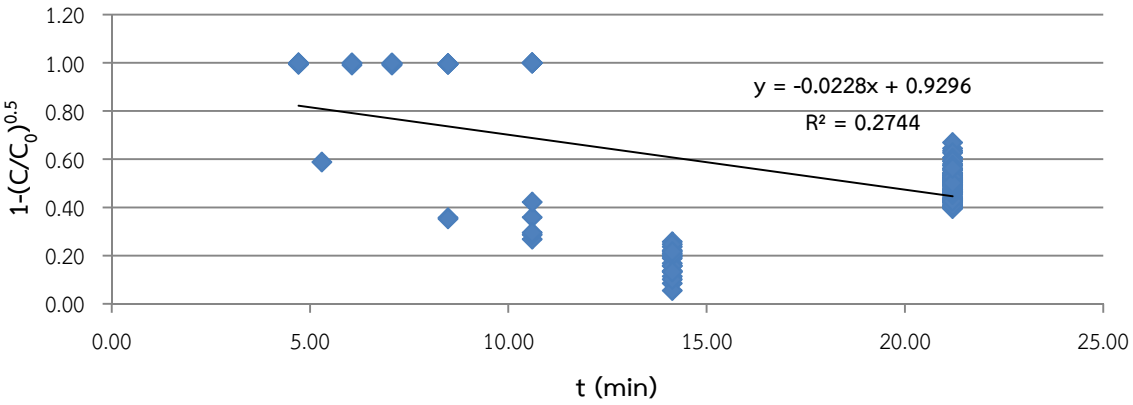


**Figure 3** Zero-Order Kinetic with Diffusion Limited Model by plotting 1-$(C/C_0)^{(1/2)}$ with t

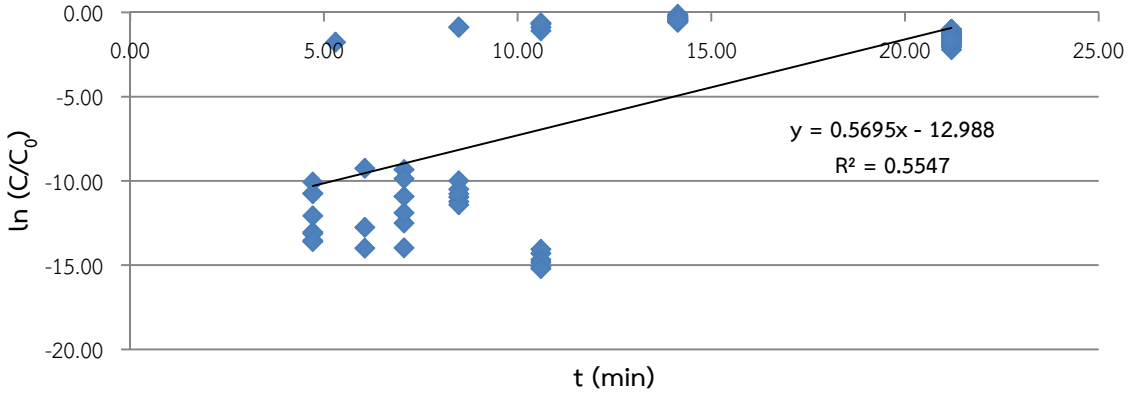


**Figure 4** First-Order Model by plotting ln ($C/C_0$) with t

## Conclusions

The kinetics of biofilter column packed with synthetics material using bacteria isolated from a petrochemical industry wastewater treatment plant. (*P. aeruginosa* S19 and *B. Cereus* O5-1/1). The Zero-Order Reaction Limited model was found for the kinetics degradation of ethyl benzene in biofilter system. The equation was $C_0$-C = (3.2192×t) - 21.513 and the constant of the kinetic reaction rate ($k_0$) was 1.8467 ppm.min$^{-1}$.

## Acknowledgement

The study was granted by the Research and Technology Institute PTT, PTT Public Company Limited. The experimental lab was generosity facilitated by Faculty of Science and Technology Thammasat University.

## References

[1] National Oceanic and Atmospheric Administration. CAMEO Chemicals version 2.7.1 [Internet]. Maryland: National Oceanic and Atmospheric Administration's Office of Response and Restoration; c2018 [cited 2019 July 6]. Available from: https://cameochemicals.noaa.gov/chemical/3625

[2] International Agency for Research on Cancer (IARC). Agents Classified by the IARC Monographs, Volumes 1-123. [Internet]. Lyon: IARC Press; 2019 [cited 2019 Jun 27]. Available from: https://monographs.iarc.fr/wp-content/uploads/2018/09/ClassificationsAlphaOrder.pdf

[3] Joseph S. Devinny, Marc A. Deshusses and Todd S. Webster, 1999. Biofiltration for Air Pollution Control. Lewis Publishers. Unites State of America.

[4] V. Saravanan, M. Rajasimman, N. Rajamohan, 2010. Biofiltration Kinetics of Ethyl Acetate and Xylene Using Sugarcane Bagasse bases Biofilter. Chemical Engineering Research Bulletin, 14 (2010): 51-57.

[5] Zarook S., Wasim A., Ahmed A. 2011. Kinetics and Modeling of $H_2S$ Removal in a Novel Biofilter. Advances in Chemical Engineering and Science, 1: 72-76.

[6] Yang Y, Allen ER. Biofiltration Control of Hydrogen Sulfide 2. Kinetics, Biofilter Performance, and Maintenance. Journal

of Air & Waste Management Association. 1994; 44(11): 1315-1321.

[7] Abumaizar RJ, Smith EH and Kocher W. Analytical Model of Dual-Media Biofilter for Removal of Organic Air Pollutants. Journal of Environmental Engineering. 1997; 123(6): 606-614.

[8] Thirawatthana P., Kajana M., Sorn S., Gamgarn T., Paritta R. and Warawut S. Biodegradation of Benzene, Toluene, Ethylbenzene and Xylene (BTEX) by Bacteria Isolate from Petrochemical Waste. At 26th Environmental Technology Conference, Environmental Engineering Association of Thailand, Bangkok, Thailand on 11-12 December 2014.

[9] Patinya S. A Study of the Bacteria Immobilization on Synthetic Media for using in Biofilter. At 26th Environmental Technology Conference, Environmental Engineering Association of Thailand, Bangkok, Thailand on 11-12 December 2014.