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Treatment of Gasoline Vapor Gas by Compost Biofilter

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I. Introduction

As leaking underground storage tanks (LUSTs) were one of the most widespread problems in these days, cleanup of petroleum hydrocarbon contaminated site became a big issue. Soil vapor extraction (SVE) technology is an applicable method for the gasoline contaminated site remediation. As of August 1995, about 45% of diverse innovative treatment technologies for superfund remedial actions were SVE technology in USA (US. EPA, 1995). Biofiltration is an emerging technology to control VOCs from contaminated waste gases including SVE vapor gases. It is more cost-effective than other technologies and does not generate secondary contaminated gases.

The objectives of this research were to evaluate biodegradation rate of TPH and BTEX in biofiltering gasoline vapor gas and to get fundamental data for several gas injection mode in the future study by evaluating removal phenomenon of gasoline vapor gas at different biofilter filling-height.

II. Materials and Methods

1. Experimental Setup

A schematic of the laboratory-scale biofilter system used in this study is shown in Figure 1. Biofiltration units consisted of a gasoline solution chamber, a vacuum air pump (GAST Vacuum Pumps, DOAP104AA, USA), a humidifier, and a biofilter reactor. This system was installed in an incubator to maintain isothermal condition of the biofilter reactor at 20℃. The reactor was composed of four transparent acryl columns with inner diameter of 5cm and each height of 25cm. Five gas-sampling ports were fitted at the height of 0, 25, 50, 75, and 100cm from the bottom of the biofilter reactor. A valve at the bottom allowed condensate to be drained from the reactor.

2. Biofilter Media

Media for biofilter unit was compost, which was produced at Nanji Composting Facility near the Nanjido landfill site in Korea. Bulk density and field capacity of the media were about 770kg/m^3 and 70%, respectively. Its pH was 8.8. Uniformity coefficient of the compost was 5. The compost was sieved through a 2 mm sieve to remove large bulking agent and inerts. A biofilter reactor was packed with about 2.0L of compost with estimated bulk density of 770kg/m^3.

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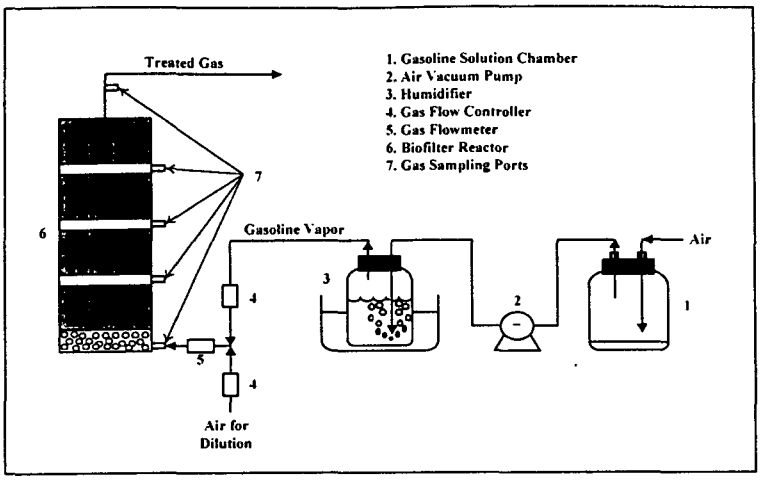

Figure 1. Schematic of laboratory-scale biofilter system.

3. Operational Condition

Moisture content of biofilter media was set to 60-80% of the field capacity and was about 50% by dry weight basis. Gasoline gas vaporized by a vacuum air pump was passed through distilled water in a glass chamber, maintained at a constant temperature of 30℃. Relative humidity of the gas was near 100%. Devinny (1998) suggested that over 95% relative humidity of the incoming gas should be kept to prevent drying-out of the biofilter filling material. Gasoline vapor gas was mixed with ambient air to control vapor concentration. A constant flowrate of diluted gasoline vapor gas was injected into the biofilter reactor in an upflow mode. Gas flowrate was 0.2L/min (6m/hr), yielding an empty bed retention time (EBRT) of 10 minutes.

4. Gas Sampling and Analytical Method

Volatile organic compounds (VOCs) in gasoline vapor gas were collected using charcoal tube (SKC, Catalogue number 226-01). A constant flowrate gas was passed through the tube by using handy sampler (KIMOTO HS-6N, Japan). The tube was packed with charcoal (coconut activated carbon), having high adsorption capacity for volatile organic compounds. The VOCs trapped in the tube were extracted by being soaked with 1 mL methylene chloride. Extracted gasoline vapor compounds after 30 minutes were analyzed by a gas chromatograph (Hewlett Packard Model 5890) equipped with an integrator (Hewlett Packard Model 3395) and a flame ionization detector. A stock standard solution for gasoline TPH was prepared from commercial gasoline fuel. A Modified GRO Mix Standard Solution (Gasoline Range Organics, Catalogue No. 4-8167) from Supelco, Inc. was used for BTEX standard. Pressure drop of the biofilter was measured by U-manometer.

Ⅲ. Results and Discussion

Figure 2 provides relationship between the loading rate and the elimination capacity for biofilters with and without adding biocide. $HgCl_2$ as biocide was added in the concentration of 6,000mg/kg by dry weight basis. The average TPH elimination capacities of the compost biofilter with and without biocide were 80%

and 20%, respectively. 20% of the loaded organic compounds were removed by the physical mechanism. TPH biodegradation rate could be calculated as follows: 80% - 20% = 60%. In case of BTEX (see Figure 3), equation slopes of BTEX removal with and without biocide were 0.85 and 0.21, respectively. Biodegradation rate of BTEX was 64% from the above calculation. Biodegradation rate of BTEX was 4% higher than gasoline TPH. The main mechanisms for gasoline TPH and BTEX removal were biological. Wright et al. (1997) reported that removal efficiencies of TPH and BTEX by biological reaction were 73% and 93%, respectively.

The relationship between loading rate and elimination capacity for each benzene, toluene, ethylbenzene, and xylene (aromatic organic compounds) was expressed as a regression equation of the first degree (see Figure 4). Equation slope of o-xylene was 0.97 and the highest among the compounds, and that of benzene the lowest (0.74). Values of Henry's law constants for BTEX were $> 10^{-3}$ $m^3 \cdot atm/mol$, meaning highly volatile compounds, and there was not big difference between their values. Benzene water solubility was over 4 times higher than other compounds (see Table 1). Transfer of contaminants from the air to the water of biofilter media is a fundamental step for biofiltration (Devinny et al., 1999). Considering only physical properties of these compounds, benzene was the most easily sorbable to the media and thought to be the most removed. In spite of water solubility of benzene, its removal efficiency was the lowest among BTEX. It may be thought because benzene is more toxic than other compounds (see Table 1). TLV-TWA and TLV-STEL of benzene were 15 and 32 mg/m^3, respectively. Webster et al. (1995) reported that removal efficiency of benzene was lower (66.7%) than toluene (85.9%).

Figure 5(a)-5(b) provide the variations in gasoline TPH and BTEX concentrations along the biofilter filling height at different input concentrations. As the experimental data indicate, most of the input TPH and BTEX concentrations were removed in the lower 50% of the filling height. Up to the concentration of 720 mg BTEX/m^3, 80-100% of input was removed in the lower 50% zone, and the remaining 50% accounted for only 0-20% of the removal incoming BTEX. This phenomenon may be attributed to a relatively higher microbial population in the incoming part of the biofilter media.

Table 1. Physical properties and health risk of BTEX

Items	Water solubility at 20℃ (mol/m^3)	Vapor pressure at 20℃ (atm)	K_H at 20℃ ($m^3 \cdot atm/mol$)	TLV-TWA[a)] (mg/m^3)	TLV-STEL[b)] (mg/m^3)
Benzene	22.79	1.25×10^{-2}	0.0054	15	32
Toluene	5.60	3.75×10^{-2}	0.0066	188	-
E-benzene	1.43	1.25×10^{-2}	0.0086	434	543
Xylene	1.50~2.07	$1.09 \sim 1.15 \times 10^{-1}$	0.0055~0.0071	434	651

[a)] Threshold Limit Value - Time Weighted Average

[b)] Threshold Limit Value - Short Time Exposure Limit

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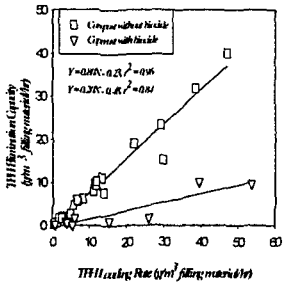

Fig. 2 Difference in elimination capacity for gasoline TPH between biocide addition and no biocide addition (biofilter filling depth = 100cm, EBRT = 10 min).

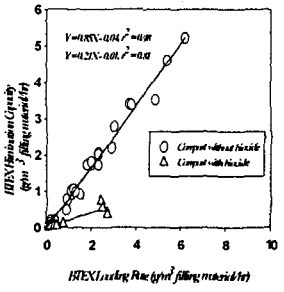

Figure 3. Difference in elimination capacity for BTEX between biocide addition and no biocide addition (biofilter filling depth = 100cm, EBRT = 10 min).

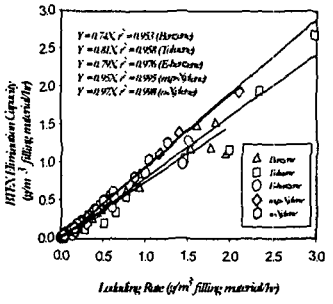

Figure 4. Elimination capacity of each benzene, toluene, ethylbenzene, and xylene in gasoline vapor gas (biofilter filling depth = 100cm, EBRT = 10 min).

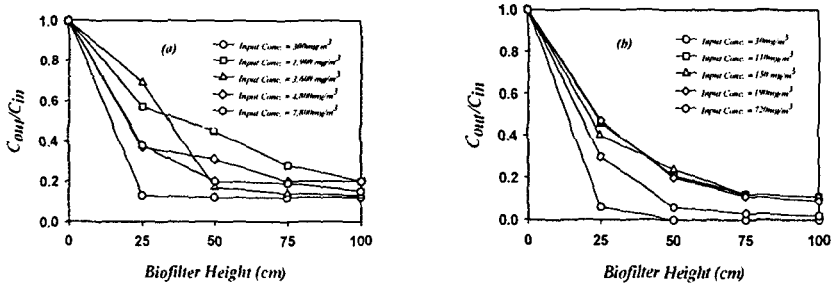

Figure 5. Concentrations profiles at different filling height; gasoline TPH (a) from 300 to 7,800mg/m^3, BTEX (b) from 30 to 720mg/m^3