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Application of tire powder and food waste compost as biofilter materials to degrade volatile organic compounds

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The present study has been conducted to verify the applicability of tire powder and food waste compost as biofilter materials to degrade volatile organic compounds. Batch and column tests were performed to determine the optimum ratio of tire powder to compost and the appropriate mixing type of two materials for removal of the selected VOCs, i.e., benzene, ethylbenzene, PCE, and TCE. According to batch tests, tire powder and compost mixture had faster removal rate than the compost. The biofilter column filled with tire powder and compost showed better VOC removal efficiency than that filled with only tire powder. In this study, the best removal rate was observed in the sandwich type column test of which the tire:compost weight ratio was 1:2.

Keywords: biofilter, biofiltration, compost, and tire

Introduction

Approximately 22.7 million tires were discarded in 1999 and their disposal poses serious environmental problems in Korea because of their poor compressibility, potential combustibility, and associated toxic fumes. About 11,230 tons of food waste per day was produced during 1999 and their disposal is difficult and expensive because direct landfilling of them has been prohibited in Korea [1]. For these reasons, there is a need for application technologies to recycle large volumes of used tires and food waste.

Considerable quantities of volatile organic compounds (VOCs) are produced from oil stations, landfills and industries such as printing and coating facilities. VOCs can be carcinogenic, odorous and generate air pollution. Thus, VOCs are facing increasingly stringent environmen-tal regulations.

Biological processes can be used for the treatment of VOC-polluted air streams. These processes involve the use of bioscrubbers, trickling filters, or biofilters [2]. A biofilter consists of a filter bed usually comprised of natural material (e.g. soil, compost, or peat) that is kept wet to maintain a biologically active layer surrounding the biofilter material particles, known as the biofilm. Biofiltration offers a number of advantages for the treatment of VOC-polluted air streams. Besides its high removal efficiency, low capital and operating cost, safe operating conditions, and low energy consumption, it does not generate undesirable byproducts and converts many organic and inorganic compounds into harmless oxidation products (e.g. water and CO_2) [3].

Compost is most widely used for biofilter bed material because it has active microorganisms and releases nutrients for microbial growth continuously [4, 5]. In the case of using activated carbon with compost, there are advantages such as physical and chemical removal, resistance to loading rate change and impact, low-pressure drop for high porosity of activated carbon, and biofilter material life extension [6].

Due to the activated carbon, the cost for biofiltration using activated carbon with compost becomes higher. Tire mainly consists of styrene butadiene rubber (SBR), which has high sorption capacity for hydrophobic VOCs [7, 8, 9, 10]. In addition, scrap tire is much cheaper than activated carbon. So it may be a substitute for activated carbon.

The objective of this research was to verify the applicability of tire powder and food waste compost as biofilter materials to remove VOCs. This research was conducted as a preliminary study.

Experiment

Materials

Target VOCs

Four target VOCs used were in this study benzene, ethylbenzene, tetrachloroethylene (PCE), and trichloroethylene (TCE). They were selected because of their relatively high detection frequency in contaminated sites and waste containment facilities.

Tire powder

Tire powder used in this study was obtained from a local manufacturer. Tire powder was air-dried without any pretreatment and sieved to obtain uniform particle sizes (< 0.6mm). Tire powder with desired sizes were then stored in a desiccator.

Compost

Compost used in this study was a composting material of food waste. The compost was stored in sealed vinyl bags at 4 °C refrigerator before use. The compost was analyzed for its moisture content (48% on wet weight basis), volatile solids (82.5% on dry weight basis), and pH (8.68).

Methods

Batch test

In order to investigate the effect of tire:compost ratio, 40 mL screw-capped Pyrex vials with a Mininert^{TM}-valve were used. The procedure for the batch tests is shown in Fig 1. The mixture of tire powder and compost with tire to compost ratio (by weight) of 2:1, 1:1, or 1:2 was placed in the vials. Total weight of the mixture in each vial was fixed to 1.5 g. Pure liquid of VOCs was injected into the small Pyrex tube placed in the vial not to directly contact the VOC liquid with tire powder. Injection volume was 0.6 of the normalized vapor pressure (P_i/P_0), where P_i is the initial vapor pressure and P_0 is the saturated vapor pressure. 10 test vials were prepared for every test. Vials were tumbled end-over-end in a temperature-controlled room (20±1°C). Headspace gas were sampled using a gastight syringe every two days. By conducting a set of control tests in which tire and compost were not introduced, losses of organic compounds during batch tests were accounted for. Initial water content of compost was 50%. For practical application, microorganisms were not inoculated.

Column test

A column biofilter system was designed and constructed, which is shown in Fig 2. The biofilter bed material (tire and compost) was enclosed in a rigid, stainless steel column, with an inner diameter of 50 mm and a height of 160 mm. Each of these columns was packed with a desired tire/compost mixing type, which was a mixture or multi layer to a height of 110 mm. The packed biofilter material is supported by a stainless steel sieve plate. A glass fiber filter was placed on (and under) the stainless steel sieve plate to prevent the biofilter material from flushing out of the column.

Sampling ports were fitted with Teflon lined rubber septa and the individual sampling ports were identified as inlet and outlet ports. Each of VOCs was placed in 300 ml Pyrex glass bottle and the volume of each was 20 ml.

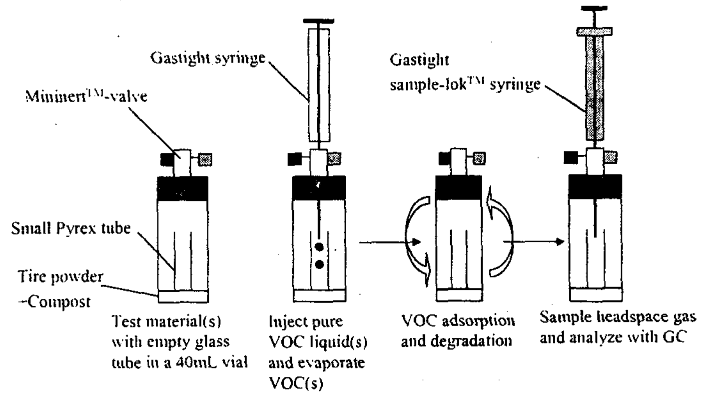

Fig 1 Schematic diagram of the batch test

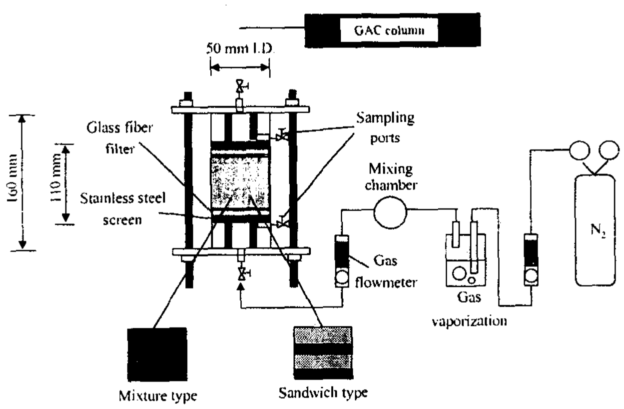

Fig 2 Schematic diagram of the column test

VOCs were volatilized by air stream and flowed into the biofilter. Gas flow rate was controlled to 10 ml/min with a gas flowmeter. All the gas lines were 1/4-in. diameter Teflon tubing. The system was operated at a temperature-controlled room (20±1°C) throughout the experiments. Inlet and outlet samples were taken using a gastight syringe.

Gas analysis

Gas chromatography (model HP-5890 chromatograph) equipped with flame ionization detection was used to analyze the headspace organic compound gaseous concentrations.

Results and Discussion

Batch test

The changes in the concentrations of target VOCs depending on the different ratios are shown in Figs 3 – 6, where C_t is the VOC concentration at a given time and C_0 is the VOC concentration of control sample at a given time.

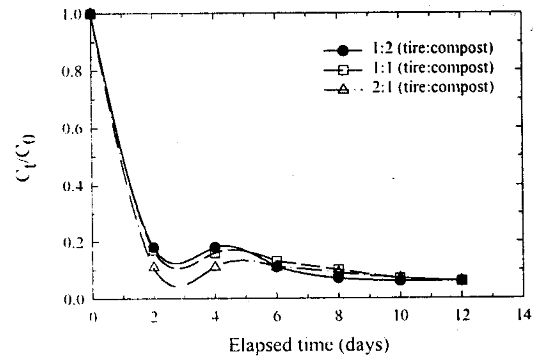

Fig 3 Benzene degradation for each tire:compost ratio

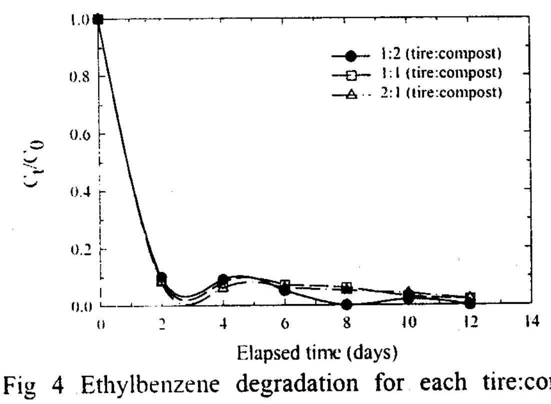

Fig 4 Ethylbenzene degradation for each tire:compost ratio

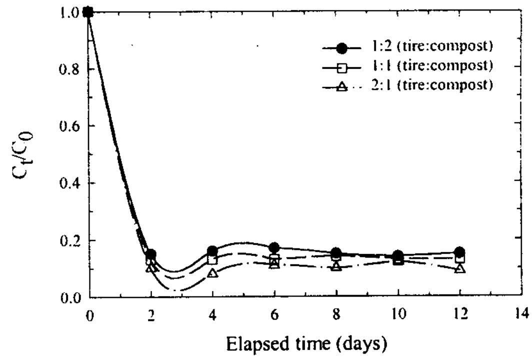

Fig 5 PCE degradation for each tire:compost ratio

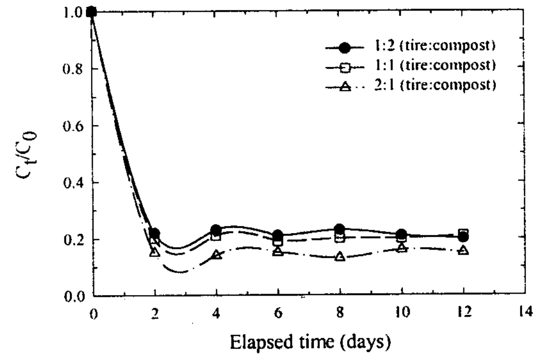

Fig 6 TCE degradation for each tire:compost ratio

VOC removal mechanism by the biofilter is physical adsorption at the first stage followed by biological degradation [6, 11]. The effect of tire:compost ratio on the VOC removal was not so significant. However, 2:1-tire:compost ratio which has the greatest tire amounts showed a little bit higher removal rate in cases of PCE and TCE because PCE and TCE could not be readily removed by the aerobic biological degradation.

The benzene degradation patterns of compost alone and tire-compost mixture were compared in Fig 7. In these tests, experimental conditions such as moisture content, total mass, and benzene injection volume were identical. At the first stage, tire-compost mixture showed a higher removal rate than compost because of high adsorption capacity of tire. Due to the biological activity, compost has continuously degraded benzene even though the rate was not as high as that of the tire-compost mixture. Thus, it seems that the tire:compost ratio need not to be as high as 1:2.

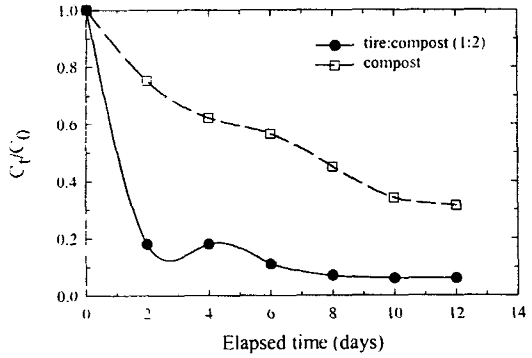

Fig 7 Comparison of benzene degradation between compost alone and tire-compost mixture

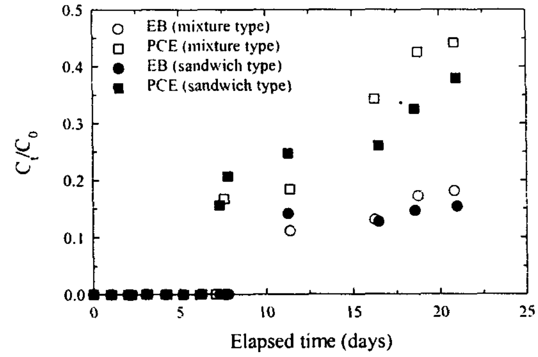

Fig 8 Breakthrough profiles of mixture type biofilter and sandwich type biofilter

Column test

From tire:compost ratio test, 1:2-tire:compost ratio was selected as composition of packed biofilter material. One biofilter was filled with the completely mixed tire powder and compost (mixture type). The other biofilter was composed of two tire layers and two compost layers placed alternately (sandwich type). Thicknesses of tire powder layer and compost layer were approximately 2.5 and 3.0 cm, respectively. Total weights of tire powder and compost introduced to each biofilter were identical.

In cases of benzene (BZ) and TCE, two types of biofilters showed similar results. Initially, in cases of ethylbenzene (EB) and PCE, the sandwich type biofilter showed better mitigation of VOCs than the mixture type biofilter. Fig 8 showed results of ethylbenzene and PCE, where C_t is outlet concentration at a given time and C_0 is inlet concentration at a given time. However, on all occasions. VOC removal was much lower than the values reported by other researchers.

A comparison of breakthrough profiles was made with the sandwich type biofilter and the tire column (Fig 9). Tire column was packed with only tire powder. Tire had a higher adsorption capacity than compost. So, if only physical removal had been considered, the tire column should have showed greater retardation than the sandwich type biofilter. However, an opposite phenomenon was observed because of biological degradation. Insufficient removal rate in this study could be improved by conducting the followings. 1) using a larger size biofilter, 2) providing moisture and nutrients continuously, and 3) inoculating appropriate microorganisms

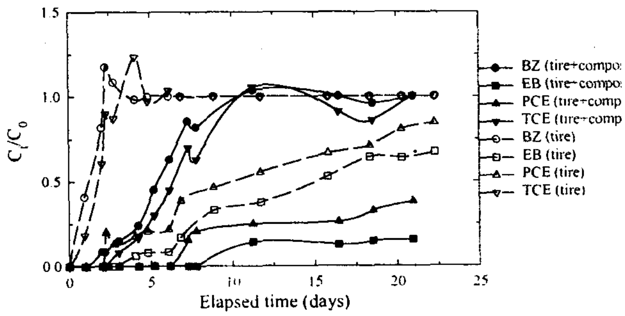

Fig 9 Comparison of breakthrough profiles between the tire-compost biofilter and tire column

Conclusions

Based on these experiments, the following conclusions can be made.

1. Among 2:1. 1:1, 1:2 of tire:compost mixing ratios (by weight), VOC removal rate was the highest in case of 2:1-tire:compost ratio at the early period (about 4 days), however 1:2-tire:compost ratio was shown to be the highest overall removal rate thereafter.

2. Initially, tire-compost mixture had a higher removal rate than compost alone because of high adsorption capacity of tire powder. Due to the biological activity, compost has continuously degraded benzene even though the rate was not as high as that of tire-compost mixture. Thus, it seems that the tire:compost ratio need not to be as high as 1:2.

3. On tire/compost mixing test, the sandwich type biofilter had a higher overall removal rate for target VOCs than that of the mixture type biofilter.

Acknowledgement

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