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3D3) Biofiltration of a Waste Gas Stream Contaminated with NH_3, H_2S and Toluene using a Novel Rock wool-Compost Media

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1. INTRODUCTION

With its significant economical and operational advantages over other physical and chemical methods, biofiltration has emerged as an effective waste gas control technology for the removal of odorous and volatile organic compounds commonly associated with olfactory nuisance and health related problems. Among the odorous compounds, ammonia (NH_3) and hydrogen sulfide (H_2S) are the most prevalent in industrial processes including food preparation, livestock farming,leather manufacturing and wastewater treatment. Moreover, hydrogen sulfide is the principal odorous component in off-gases from publicly-owned treatment works (POTWs). These compounds are irritating and smelly due to their low odor thresholds of 1.1 and 37 ppb for H_2S and NH_3, respectively. On the other hand, POTWs and other sources also contain a wide range of other odorous compounds, air toxics, and volatile organic compounds. Of the VOCs, toluene is the most frequently detected. Toluene is also predominant in industries that use it as solvent and in the production of resins, plastics, explosives, agrochemicals and pharmaceuticals. There were studies on the removal of either NH_3 and H_2S or H_2S and toluene; however, a mixed gas system contaminated with these three compounds has not yet been studied. Accordingly, the type of medium to be used has a great impact in a biofilter system. The medium needs to be suitable to house microorganisms responsible for oxidizing or degrading gas pollutants. At the same time, it should be mechanically firm and should provide good air flow and high gas to liquid transfer rates. Hence, a combination of organic and inorganic properties would be best for a biofilter media.

In this study, we evaluated the effects of increasing the concentration of one compound to the removal efficiencies of the other compounds in a tri-component mixed gas system of NH_3, H_2S and toluene using a novel rock wool-compost media developed in a previous study. We also investigated the elimination capacities, removal profile and pressure drop along the biofilter height, and the pH, nitrate/nitrite and sulfate concentrations of the biofilter leachate.

2. MATERIALS AND METHODS

2.1 Biofilter media and Inoculation

The novel medium consisted mainly of rock wool and compost in 70:30 weight ratio. Water was added to effect wetting and thorough mixing; a small amount of activated carbon was simultaneously added. Organic and inorganic binding solutions were added when the mixture had become homogenized. The resulting mass was molded into spherical shapes, 0.8-1.0 cm in diameter, and then placed in a drying oven at 60℃ for 3 to 4 hours. The medium's properties were: (i) bulk demsity, 0.53 g/ml; (ii) true density, 2.44 g/ml; (iii) porosity, 78.5%; and (iv) water holding capacity, 0.72 g H_2O/g medium. Initial moisture content was 40% and packing density to the biofilter was around 820 kg/m^3. The medium was seeded with gas-specific strains grown in mineral medium. The strains were previously isolated from activated sludge taken from the Yongin wastewater

The strains were previously isolated from activated sludge taken from the Yongin wastewater treatment plant in Korea. The strains used were AMM, *Pseudomonas sp* SUL4 and *Pseudomonas sp* TAS4B strains for NH_3, H_2S and toluene, respectively.

2.2 Experimental Setup

The experiment was conducted as shown in Figure 1. Two biofilters were setup: BRC 1 and BRC 2. Initially, all columns were fed with waste gas contaminated with about 50 ppm each of NH_3, H_2S and toluene. After a few days of acclimatization, the gas concentrations were increased to about 100 ppm. After two weeks, the NH_3 concentration in BRC1 was increased to around 200 ppm while maintaining the H_2S and toluene concentrations to around 100 and 50 ppm, respectively. On the other hand, the H_2S concentration in BRC 2 was increased to around 200 ppm while maintaining the NH3and toluene concentrations to 100 and 50 ppm, respectively. The waste gas flow rate to the biofilters wasmaintained at 10 L/min corresponding to an EBRT of 25 seconds. The biofilters also received daily spray of water.

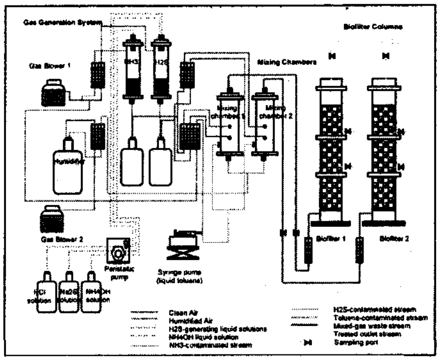

Fig. 1. Schematic diagram of the mixed gas experiment

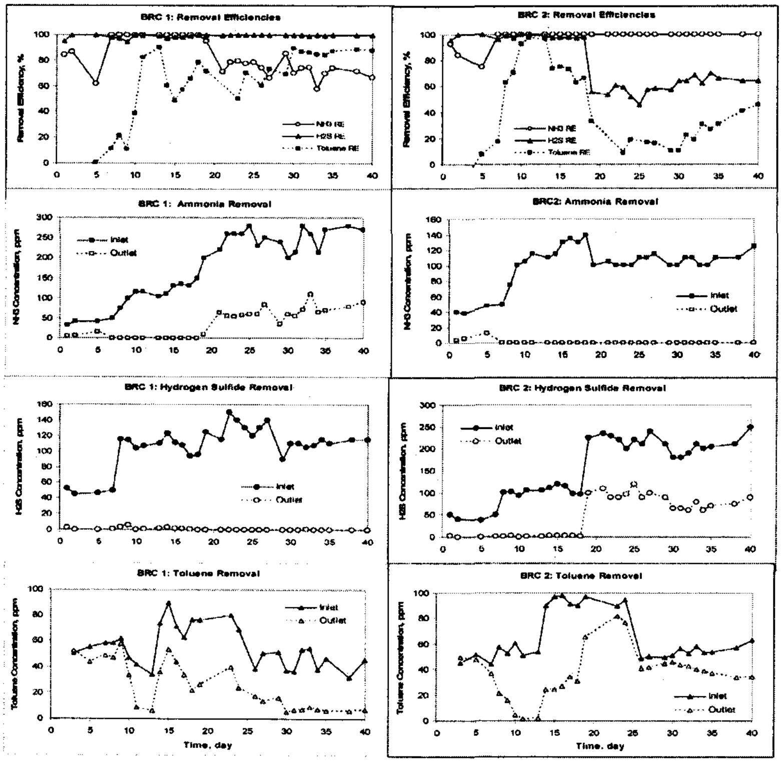

Fig. 2. Removal efficiencies of and Concentration profiles of NH_3, H_2S and toluene in BRC 1 and BRC 2 biofilter columns.

2.3. Analytical Methods

Three sampling ports were positioned 16, 38 and 54 cm from the bottom of the biofilters. NH_3 concentration from the inlet and from these ports was analyzed by impingement method into 0.05 N H_2SO_4 solution and then measured using NH_3 selective ion probe (Orion). H_2S gas was determined using a Multi-RAE gas analyzer. Higher concentrations of NH_3 and H2S were determined using Gastec tubes with the highest range up to 500 ppm. Gas samples were also taken from each port and analyzed for toluene using a gas chromatograph equipped with a flame-ionization detector (GC-FID). Leachate was taken daily from the biofilters and was analyzed for pH (Orion) and nitrate/nitrate (spectrophotometrically by Bran Lubbe Automatic Analyzer 3) and sulfate concentrations (ion chromatography by Waters).

3. RESULTS AND DISCUSSION

3.1 Gas Analyses

The performance of BRC1 and BRC 2 in removing NH_3, H_2S and toluene is shown in Figure 2. During the 50 ppm initial loading, H_2S and NH_3 were easily removed (above 80%) while toluene was not removed not until after the first week. When the concentrations were raised to 100 ppm, both biofilters easily adapted and removed almost completely the NH_3 and H_2S in the inlet stream. However, toluene was not significantly removed. In the case of BRC 1, when the concentration of NH_3 was doubled, the removal efficiency of H_2S was not affected and was still completely removed. However, the NH_3 removal declined from 100% to about 70~80%. The NH_3 removal did not further improved until the conclusion of the experiment. On the other hand, in BRC 2, doubling the H_2S concentration did not affect the NH_3 removal. Increasing the H2S inlet concentration caused its removal efficiency to plunge to about 50%. The removal efficiency did not improve anymore. In the case of toluene, increasing the NH_3 loading in BRC 1 favored its removal. On the other hand, increasing the H_2S concentration in BRC 2 significantly decreased toluene removal to about 10%. But, as the experiment was proceeding, the toluene removal in BRC 2 gradually increased to about 30%. From here, we can say, that increasing H_2S loading has inhibitory effect to toluene degrading microorganisms.

3.2 Leachate Analysis

Leachate samples from columns were analyzed for pH and ion concentrations. From Figure 3, we can say that the pH of both biofilters varied between pH 7 and 9. This range is still good for a biofilter system. The medium in BRC 2 did not become acidic which is usually the case

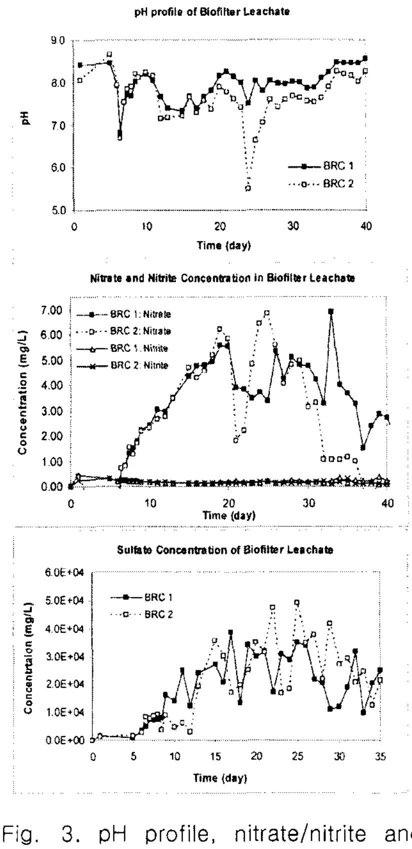

Fig. 3. pH profile, nitrate/nitrite and sulfate concentrations in biofilter leachate.

for a biofilter treating only H_2S. The nitrate concentrations in BRC 1 are higher than in BRC 1 which was expected since BRC 1 was subjected to higher NH3loading. The same trend was observed in BRC 2 for the sulfate concentration. The difference in the sulfate concentrations in BRC 1 and BRC 2 is not great since even H_2S loading was higher in BRC 2, the removal rate is just around 50%. Their elimination capacity does not differ so much.

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