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A pilot-study on treatment of a waste gas containing butyl acetate, *n*-butyl alcohol and phenylacetic acid from pharmaceutical factory by bio-trickling filter

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Abstract

A bio-trickling filter packed with fibrous balls, ZX02, packing material was tested to treat a mixed waste gas containing butyl acetate (BA), *n*-butyl alcohol (*n*-BA) and phenylacetic acid (PA), which were discharged from penicillin workshop in a pharmaceutical factory. In order to investigate the effect of various factors such as inlet loading and spray water flow rate on the removal rate of these three volatile pollutants, a field experiment was carried out continuously for more than 3 months using a pilot bio-trickling filter and effluent from a wastewater treatment plant was used as spray water during the pilot experiment. The removal rates of BA, *n*-BA and PA was 95%, 92% and nearly 100%, when their inlet concentration was lower than 2200, 2400 and 370 mg m^{-3}, respectively. To maintain 90% removal of BA, *n*-BA and PA, acceptable maximum inlet loadings cannot exceed 373.4, 317.2 and 209.5 g m^{-3} h^{-1}, respectively. The effluent from the secondary sedimentation tank of the pharmaceutical wastewater treatment plant can be used as spray water, and its optimal flow rate was determined to be 9.5–10.5 L h^{-1}. The bio-trickling filter had significant ability to resist shock of high inlet loading while maintaining low resistances to air flow. Therefore, it can be operated for long-term without frequent backwashing.

Keywords: Bio-trickling filter; Butyl acetate; *n*-Butyl alcohol; Phenylacetic acid; Volatile organic compounds

1. Introduction

Currently, penicillin is widely used as antibiotics because of its high cure rate and low costs in China. Penicillin is produced through a series of unit processes, including fermentation, cell disruption, filtration, solvent-extraction, washing, counter-extraction, co-boiling crystallization and desiccation. The solvents used are typically butyl acetate (BA) and butyl alcohol (*n*-BA). In order to reduce cost, it is necessary to recover the solvent by rectification (Fig. 1). The raffinate after rectification still contains considerable amounts of BA and *n*-BA. In addition, phenylacetic acid (PA), which is one of substrates using to produce penicillin is also concentrated in the raffinate. An irritant waste gas is resulted from the discharged raffinate after rectification process, and these volatile organic pollutants are emitted into the air when the raffinate is discharged. This polluted gaseous discharge can have significant health impact on the workers as well as the surrounding communities.

The literatures identified many chemical, physical and biological treatment methods for various gases [1–5]. However, recently biological methods have become the main techniques because they have many advantages, such as high removal rate, low investment and operating costs, low energy consumption and less secondary pollution [6–9].

During the 1970s, major improvement in biofilteration technology was made in Europe where it has been successfully applied to control both organic and inorganic air pollutants from a variety of industrial and public sector sources [10–13]. For example, The Netherlands and Germany established biofilteration technology as main air pollution technology for volatile organics [14]. Lu used a bio-trickling bed to remove BA in a lab-scale reactor as a single organic compound and the removal rate was high [15]. Almost complete BA removal could be achieved for influent carbon loading between 12 and 177 g/(m^3 h). Sun,

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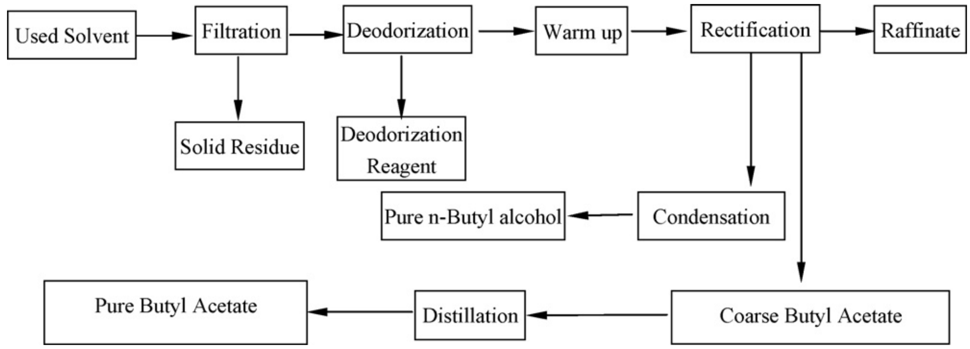

Fig. 1. Schematic flow chart for the recycle of butyl acetate and *n*-butyl alcohol.

Li and Liao had also carried out theoretical study on microbiological treatment of volatile organic compounds (VOCs) based on lab-scale experiments [16–20]. Nevertheless, in previous reports, single compound or compounds made by several pure substances was used as study objects and the inlet loading was not varied. Removal of multi-components mix gases and the effect of dynamic inlet loading on removal efficiency were rarely investigated. In addition, the practical application of bioreactors that were used to remove mixed gas containing BA, *n*-BA and PA has not been reported yet. It is very important and useful to understand the removal principle of mixed gas for the researchers and the industrial practitioners.

In this study, a field pilot experiment was carried out continuously for more than 3 months by using a bio-trickling filter with ZX02 packing. It was used to remove BA, *n*-BA and PA from a waste gas stream directly from a penicillin workshop. In this study, operational parameters such as inlet organic waste gas concentration, spray water flow rate, and elimination capacity, resistance to shock of inlet loading to the bio-trickling filter were examined in detail. The research results should lay the foundation for the optimal design and operation of a full-scale bio-trickling filter.

2. Materials and methods

2.1. Experimental equipments

The pilot-scale bio-trickling filter provided by Shanghai Best Environmental Engineering Co. (China) had an outside dimension of 2800 mm × 300 mm × 1650 mm and working volume of the filter was 0.075 m^3. The void fraction of the bioreactor was 0.70. The filter was made up of plexiglas and the whole system was automatically controlled (Fig. 2). For example, frequency and flow rate of spray water were controlled by an electromagnetism valve with a time-limit relay. The most important part of the equipment was the biological tower packed with the ZX02 carrier. ZX02 was a commercial product, which was also provided by Shanghai Best Environmental Engineering Co. (China) and consisted of many round fibrous balls (diameter of 35 mm and bulk density of 82 kg/m^3). The carrier was strongly resistant to acidification and erosion, and they had large surface area and good flow distribution characteristics. In order to check the removal rate of the waste gas, the tower was equipped with three sampling ports (S1, S2 and S3) at tower height of $H_{S1} = 270$ mm, $H_{S2} = 452$ mm and $H_{S3} = 340$ mm.

The flow rate of inlet gas was controlled between 3.5 and 9.5 $m^3\,h^{-1}$ during the experiment. The spray water was either tap water added with inorganic nutrient components or effluent wastewater from the secondary sedimentation tank in a wastewater treatment plant of this factory. The volatile organic waste gas was introduced into the biological tower from the bottom by an air compressor after flowing through a flow meter and the gas treated by biological tower exhausted from top. Liquid in the storage tank was sprayed regularly into biological tower from the top by a centrifugal water pump. DO concentration in the spray water was between 6.23 and 6.81 L^{-1}. Start-up and operation of the bio-trickling filter was carried out in warm season and inside temperature of bio-trickling filter was between 27 and 35 °C. Temperature was not a limited factor because most microorganisms could grow well in this temperature range.

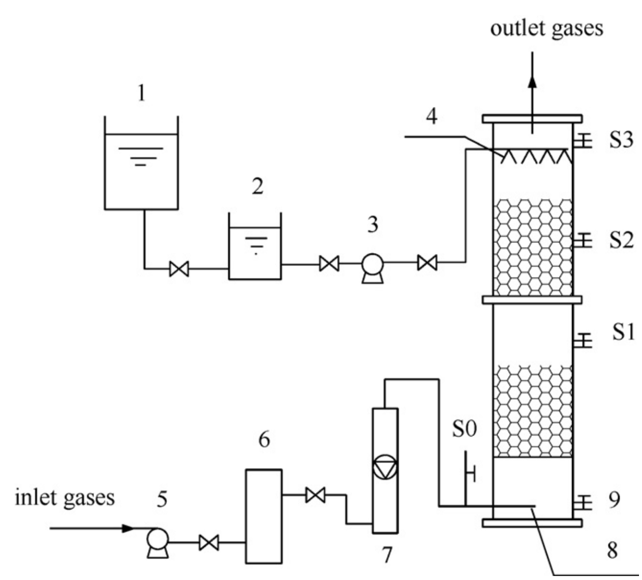

Fig. 2. Schematic diagram of the pilot-scale bio-trickling filter system. 1: storage water tank; 2: buffer water tank; 3: water pump; 4: water distributor; 5: air compressor; 6: buffer gas pot; 7: flow meter; 8: air distributor; 9: effluent water port; S0, S1, S2, S3: sampling port.