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Research Article

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Ammonia odours removal by gasphase biofilter through nitrification and Anammox processes

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ABSTRACT

Biofilter study was carried out on 1.2 L gas phase filter for the removal of ammonia at inlet concentration around 250 ppmV. Removal efficiency (RE) of biofilter remained in the range of 90–99% during the stable period of operation (80 days) at empty bed residence time (EBRT) of 20 s whereas RE of biofilter dropped to 65% when the EBRT was 10s. Metabolites were observed as ammoniacal nitrogen, hydrazine, nitrite and nitrate were formed during the degradation pathway in biofilter bedding material of a mixture of agricultural residue. It was inoculated with mixed microbial cultures of nitrifying and anammox bacteria were isolated from the active sludge of ETP of different industries.

Keywords: Biofilter; Ammonia; Nitrification; Anammox; Gas

INTRODUCTION

Ammonia is emitted into the environment from farmed livestock, the petrochemical industry, oil refineries, metal assembling, food, textile plants, pulp and paper industries, , wastewater treatment plants and composting plants [1, 2]. Ammonia is a colourless, toxic, reactive and corrosive gas with a very prickly odour. Ammonia vapour is an irritant to the eyes and the respiratory tract, and acute exposure to high concentrations can lead to death within minutes [3–5]. These emissions, in addition to its own toxicity, constitute a source of olfactory nuisance [5]. The traditional methods for treatment of ammonia are based on physical and chemical processes, such as adsorption on activated carbon, wet scrubbing and condensation, which are for the most part costly and produce optional waste that may require further treatment or transfer, along these lines making extra ecological issues [1, 3, 6]. Recently, biological processes have received much attention as an alternative for treatment of polluted air [7, 8]. The principle of biofiltration is relatively simple; a polluted air stream is passed through a porous packed bed on which pollutant degrading cultures of microorganisms are immobilized [9]. Biofiltration is an emerging technology that offers a number of advantages over traditional methods of air pollution control for the treatment of low concentration contaminated air streams. Besides it is highly efficient removal of pollutants, low capital and operating costs, safe operating conditions and low energy consumption, it does not generate undesirable by-products and it converts many organic and inorganic compounds into harmless oxidation products [10, 11]. Also, the simplicity of design has been cited as a reason for the popularity of biofilters [11]. Biofiltration of ammonia waste gas streams has been studied by a number of researchers. The packing material for the column has included organic and inorganic packing material inoculated with isolated and mixed microorganisms [8, 12-15]. The biofiltration systems are mainly based on nitrification, convert ammonia into nitrite and nitrate, and, as a result, end up with a highly loaded go through mixture of ammonium, nitrite and nitrate. Its main disadvantage is an accumulation of nitrites and nitrates in biofilter bedding material, hence leading to failure of biofilters in most of the cases due to inhibiting affects of nitrites and nitrates on ammonia oxidizing bacteria. Moreover, disposable of this bedding material is a major problem. To overcome this problem, the study was to express the possibility to obtain nitrogen (N_2) gas from ammonia emission abatement through the process of simultaneous nitrification and anaerobic ammonium oxidation

(anammox) processes by using gas phase biofilter.

EXPERIMENTAL SECTION

Isolation and enrichment of nitrifying bacteria

Soil and activated sludge samples of different industrial effluent treatment plants were screened for isolation of nitrifying bacteria. Nitrogen limiting media [7] were used for enrichment of these bacteria at different concentrations. These were grown under well agitated aerobic conditions in a rotary shaker (150 rpm) at 30^{o}C.

Isolation and enrichment of anammox bacteria

Soil and activated sludge samples of different industrial effluent treatment plants were screened for isolation of anammox bacteria. Designed synthetic wastewaters with 1.2 ratios of nitrite/ammonia [15] were used for enrichment of these bacteria at different concentrations. These were grown under anaerobic conditions at 30^{o}C.

Activity batch tests

Two Batch experiments were conducted to determine the nitrifying and anammox bacteria degradation potentiality of ammonia. Nitrifying microorganisms batch experiment was conducted with the concentration 100mg/l ammonia with HRT of 4 days at 30^{o}c and pH of 7. At an end of the experiment analyses the ammonia, nitrite, nitrate concentrations were observed as 2.5mg/l, 45mg/l and 35mg/l, respectively. It indicates the nitrifying bacteria existence in the batch experiment by converting the ammonia to nitrite and nitrate. Simultaneously anammox bacteria batch experiment was conducted with the concentration 100mg/l ammonia and nitrite 80mg/l with HRT of 10 days at 30^{o}c and pH of 7 under strictly anaerobic conditions. At an end of the experiment examination the ammonia, hydrazine, nitrite and nitrate concentrations were observed as 2mg/l, 0.5mg/l, 3mg/l and 1 mg/l, respectively. Hydrazine indicates the anammox bacteria existence in the batch experiments.

Preparation of biofilter packing material

A mixture of agricultural residue (coir pith, rice husk and saw dust were blended in equal proportion) was used as bedding material, which were obtained locally from Hyderabad, India. The filter material was characterized for various parameters like particle size, moisture content (wet based), bulk density, water holding capacity and pH. Enriched mixed microbial strains of anammox bacteria were cultured with 0.4 kg of bedding material and it was loaded up to 3rd part of the biofilter from the bottom of the filter column and MC was maintained 70-80% to the formation of anaerobic zones. Simultaneously enriched mixed microbial strains of nitrifying bacteria were cultured with 0.1 kg bedding material and it was loaded remaining part of the upper side biofilter and MC was maintained 55-60% to maintain aerobic zones.

Biofilter experimental setup

The gas phase biofilter column was connected into ammonia gas cylinders with air inlet facility. Air and ammonia flow rates were controlled with regulatory knobs for producing desired concentration of ammonia gas. Biofilter was a cylindrical glass column having an inner diameter of 8.1 cm and a height of 71 cm. The packing material was filled up to 51 cm so that active volume was 1.2 L. The biofilter column was provided with sampling port to gather bedding material for sampling during the experimentation. Biofilter column was also provided with inlet and outlet gas sampling port for the analysis of ammonia in air. Water sprinkling arrangement was made at the top and middle of the biofilter column and connected with a pump to maintain the MC in the range of 55–60% in upper part of bedding material and 70-80% was in a lower part of bedding material as per the requirement.

Biofilter experimental procedure

Experiment for ammonia bio-oxidation was carried out for nearly 90 days to evaluate the removal efficiency (RE) of the packed microbial cells under different operating conditions. Ammonia gas was supplied from a commercially available standard gas cylinder and was mixed with air to obtain the desired concentrations. The concentrations were varied from 10 to 250 ppmV, while the flow rates were adjusted to give an empty bed residence time (EBRT) of 60, 50, 40, 30, 20 and 10 s. During the first few days of continuous biofilter operation, both the concentration and flow rate was kept low in order to expose and adaptation of microorganisms to the new environment. Later, the inlet concentrations were increased in intermittent steps and each step was operated till the outlet concentration was noticeably low (<1 ppm). The temperature in the biofilter was closely held at ambient temperature (25-30^{o}C) throughout the experimental period.

Analytical methods

Inlet and outlet ammonia gas concentrations of biofilter were analyzed daily using RAE analyzer with PID sensor (Tokyo, Japan). Bedding material was analyzed for ammoniacal nitrogen, nitrite and nitrate using a UV–visible spectrophotometer (Perkin-Elmer lambda 25) as per standard methods [16]. Hydrazine was determined by

spectrophotometer method [17, 18]. pH was determined with pH meter (Elico Pvt Ltd) and temperature and pressure drop were measured with a mercury thermometer and U-tube manometer respectively. Air flow rate to biofilter was measured by rotameter.

RESULTS AND DISCUSSION

Bedding material

Biofilter bedding material (Mixture of agricultural residue-coir pith, rice husk and saw dust) was having the bulk density of 0.62 g/cc, MC of 70-80%, 55-60%, pH 7.0, particle size in the range of 1–3 mm, water holding capacity of 81% and pressure drop was negligible.

Performance of the biofilter

Biofilter was operated by gradually increasing the inlet concentration of ammonia gas in the range of 10-250 ppmV at an EBRT of 60 s for 30 days. It could be observed that (Fig. 1) performance of the biofilter in terms of RE crossed 90% on the 16th day of operation of the filter and remained steadily in this range for initial 30 days of operation. This showed that two weeks are needed for proper acclimation of microbial consortia over filter bed for effective degradation of ammonia. The constant performance of the biofilter from 16th day to 30th day (RE in the range of 90–99%) indicated that the enriched strains have the highest ammonia degrading ability. The operation of the filter were continued at the inlet concentration around 250ppmV beyond 30 days (until 40 days) to understand the performance dynamics of biofilter by decreasing the EBRT (Fig. 1) in a stepwise manner at standard intervals (EBRT-50 s on the 30th day, EBRT-40 s on 40th day). It was observed that RE of the biofilter remained more or less in the range of 90-99%. This trend indicated that microbial degradation process is very essential in analogous with phase transfer, absorption and adsorption to maintain the performance of the filter in the range of 90-99% RE for longer periods of time. Biofilter was operated further by decreasing the EBRT to the level of 10 s in a stepwise approach (EBRT-30 s on the 50th day, EBRT-20 s on 60th day). The RE of biofilter remained high at 90-99% till the EBRT was 20 s, but it dropped to 65% when the EBRT was reduced to 10 s. Therefore, EBRT of the biofilter was brought back to 20 s. It was operated for a period of 10 days at this EBRT. During this phase, RE of the biofilter reached back to the original RE in the range of 90–99%. It could be derived from the results that present configuration of the biofilter could be operated at an EBRT of 20 s in the inlet connotation of ammonia around 250 ppmV. MC of biofilter was maintained in the range of 55–60%, 70-80% during the entire period of operation on an upper part of bedding material, a lower part of bedding material, respectively.

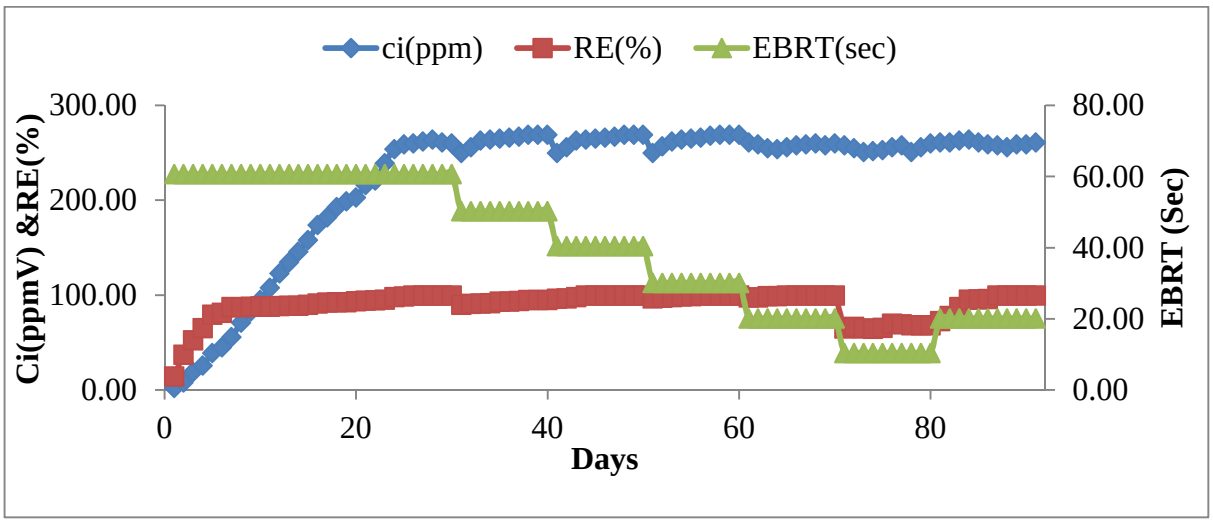

Fig.1: Biofilter performance analysis

Product analysis

The concentrations of ammoniacal nitrogen, hydrazine, nitrite and nitrate in the biofilter packed bed material was analysed at different time intervals of biofilter operation. The concentration of ammoniacal nitrogen, hydrazine, nitrite and nitrate in the bedding material before start-up was 0 mg/kg wet bed. On the first day operation onwards the concentration of ammonium increased gradually. This increase is related to absorption of the highly soluble ammonia in the packing material; after that, the concentration of ammoniacal nitrogen decreased during the whole period of operation of the biofilter due to the simultaneous nitrification and anammox process. The concentration of nitrite and nitrate was increased to 57 mg/kg and 10 mg/kg wet bed during the biofiltration operation. These concentrations were increased gradually in upper parts of the biofilter bedding material. There was a reduction in the

concentration of nitrite and nitrate in the upper part of biofilter bedding material; these were attributed to washing of nitrite and nitrate from the packing material. It can be seen that the ammonia absorbed by the filter bed was ultimately converted to nitrite and nitrate by nitrifying microorganisms after the acclimation period. Coming to lower part of biofilter (remaining 3parts of bedding material) ammoniacal nitrogen, hydrazine, nitrite and nitrate concentrations were 2mg/kg, 1mg/kg, 1mg/kg, and 2 mg/kg wet bed, respectively during the biofilter operation. It is indicating that presence of anammox bacteria by maintaining the anaerobic zones. Due to this reason ammonia and nitrite was reduced simultaneously by converting onto the N_2 gas.

CONCLUSION

Biofilter was found to be good to get RE in the range of 90–99% at ammonia inlet concentration around 250 ppmV at EBRT of 20 s. Biofilter bedding material was inoculated with mixed microbial cultures of nitrifying and anammox bacteria and formation of metabolites observed as ammoniacal nitrogen, hydrazine, nitrite and nitrate during degradation pathway of ammonia. This study reveals that possibility to obtain N_2 gas from ammonia emission abatement through the process of simultaneous nitrification and anammox processes by using gas phase biofilter.

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