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A high performance biological degradation of trimethylamine: Experimental study and mathematical modeling

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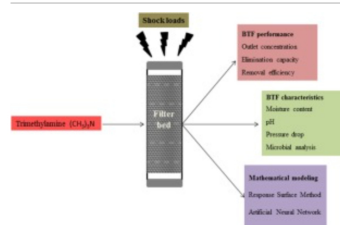
Highlights

- A continuous packed bed filter shows good performance at high TMA loading rate.
- Filter bed undergoes different shock loads and shows a good resilience capacity.
- A maximum of 100% removal efficiency was observed by Ochrobactrum and Agromyces sp.
- Highest elimination capacity of 175.2 g m⁻³ h⁻¹ was achieved.
- RSM and ANN models have shown a good fit with experimental data.

Abstract

A bench scale Biotrickling filter (BTF) packed with polyurethane foam seeded with potential TMA degrading bacterial strains (*Agromyces* and *Ochrobactrum* sp.) was tested to eliminate TMA from ambient air. BTF was functioned constantly for a period of 125 days at retention time of 180 s and 90 s corresponding to the different loading rate of 14.4–232 g m⁻³ h⁻¹. The maximum elimination capacity attained in the study was 160 g m⁻³ h⁻¹ with the removal efficiency above 95%. Low, medium and high shock loads of higher concentration were applied to the BTF during the operational period. The BTF has recuperated its performance after each shock loads which shows its good resilience capacity. The performance of the BTF was modeled first time using RSM and ANN algorithm to predict the outlet concentration, elimination capacity and removal efficiency of TMA. Both the algorithm can efficiently be employed to model the BTF performance for degrading TMA.

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Introduction

INTRODUCTION

Trimethylamine i.e. (CH₃)₃N is among the main source of odor discharged from several industrial units and is difficult to eradicate [1]. The common sources of gaseous Trimethylamine (TMA) are fishmeal processing plants [2,3] wastewater treatment plants [4], waste landfills, hog manure, and livestock farms [5,6]. TMA is a colorless gas with a low threshold limit and is potentially toxic to human health and considered carcinogenic [7,8]. TMA has been distressing the environment by subsidizing to the greenhouse effect, eutrophication and acid rain [[9], [10], [11]]. Therefore, TMA emission from various sources must be reduced up to reasonable limits for the betterment of the environment and human health. In recent times, biological treatment has been established as an effective and robust technology for eradicating various odorous gases and pollutants. Biological treatments have been highly efficient, economical and eco-friendly options for the removal of low concentration of gaseous pollutants, which are broken down to simple and non-toxic form [12]. The key component in the biotreatment procedure is the employment of microbial flora [13]. Several studies have been reported to show an effective removal of TMA with the use of bacterial species viz *Curvibacter* sp, *Sphingobacterium* sp. [3], *Paracoccus* sp. [14], and *Aminobacter* [15]. The metabolic pathway of TMA degradation involves its mineralization to dimethylamine (DMA), which further is mineralized to monomethylamine (MMA) and finally into Ammonia [14]. Once the system was established, the most significant phase in a treatment procedure is modeling to establish the proficiency of the system. The treatment system models can be developed in a deductive manner or by statistical modeling. Developing such models require a precise assessment of certain factors which are required to resolve the understanding of the complex mechanism. Likewise, during the process optimization, a single parameter is changed at a time and keeping the other parameters constant. This procedure is not only a long process which also not describes the effect of other parameters in the operation and the interactions among them. The precise assessment of certain parameters includes intricate practical services and skill, the lack of which hampers the model's accuracy and confines its performance and consistency. In the present study, biotrickling filter was employed with *Ochrobactrum* and *Agromyces* sp. derived from the sludge of Indian Oil Corporation Limited (IOCL), Assam. The microbial culture was found to be highly efficient in the mineralization of TMA and its derivatives. In the BTF packing media (commonly inert material) is a vital component which provides support the microorganism to proliferate and nutrient is recycled through the filter (Schiavon et al., 2016) [16]. BTFs have been found very competent in the removal of various pollutants as it provides a better mechanism over pH and other operational conditions in the filter system. Earlier studies on TMA treatment with BTFs application has focused on the treatment of high inlet loads [15,17,18]. But these studies have not been further explored with BTFs modeling regarding TMA removal and elimination. Modeling of the biofilters is applied to plaid the performance with process-based models. The models are related to the ability to evaluate the mass balance relationship, degradation kinetics, and other factors [19]. Hence, this study will elucidate the in depth understanding of biological treatment of TMA seeded with *Ochrobactrum* and *Agromyces* sp. and parameters which will help to deliver the crucial effect.

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Microorganism and culture medium

Activated sludge assembled from Indian Oil Corporation Limited (IOCL), Assam was customized for developing the TMA degrading microbial flora. The supplementation was provided with mineral salts and TMA as a sole energy source on a batch scale. After systematic maintenance of 120 days, enhanced TMA mineralizing microorganism centrifuged (6500 rpm, 8 min) and harvested. Bacterial growth was observed by spectrophotometer at 600 nm. Microbial colonies were isolated by diluting the culture in ...

BTF performance and TMA removal

A BTF packed with polyurethane foam as supporting material was immobilized with *Agromyces* and *Ochrobactrum* sp. for the treatment of gaseous TMA at the EBRT 180 s

and 90s. The profile of TMA inlet (IC) and outlet concentration (OC) with the removal efficiency (RE) have been presented in Fig. 3 for an operation period of 125 days. It was estimated that the accumulation of ammonia in the filter bed has shown inhibition in removal operation [28]. No gaseous ammonia was detected during the course ...

Conclusion

A BTF immobilized with *Agromyces* and *Ochrobactrum* sp. was successfully tested for a period of 125 days under a very high loading rate. Removal efficiency around 99% was observed throughout the routine of the BTF, only a fall was observed during the shock loads and a loading rate above $160 \text{ g m}^{-3} \text{ h}^{-1}$. The BTF has productively encountered the different shock loads during the operational period which shows a good resilience capacity. RSM and ANN have yielded much promising outcomes when ...

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. ...

Acknowledgement

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2021, Journal of Environmental Chemical Engineering

Citation Excerpt :

...Methanol exposure can cause respiratory irritation and damage on nervous system [9]. Among the various solutions for VOC treatment, biological ones like biofiltration are usually reliable and cost-effective [10]. Biofilters have easy and environmentally friendly operation recommended by the European Commission for VOC abatement having concentrations < 2 g.m⁻³ [11]....

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Efficient degradation of trimethylamine in gas phase by petal-shaped Co-MoS₂ catalyst in the photo-electrochemical system

2021, Chemical Engineering Journal

Citation Excerpt :

...TMA is frequently found in effluents derived from fishmeal processing plants, wastewater treatment plants, waste landfills, and livestock farms [4–7]. TMA has been affecting the environment with the greenhouse effect, eutrophication and seriously endangering human health by inducing health complications such as headaches, nausea, irritating to the eyes and the respiratory system with 15 ppm of TMA [8,9]. The Occupational Safety and Health Administration [OSHA] requires that TMA should be reduced below threshold limit i.e. 10 ppm for 10 h [10,11]....

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