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Removal of Volatile Organic Compounds using the Biofilteration Process

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Abstract—*Air pollution is the main risk to human health and natural resources. Air pollution is mainly caused by burning of fossil fuels, air emission from chemical and manufacturing industries, mining operation and agricultural activities. Major air pollutants consist of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs). Methanol and alkanes (e.g. n-hexane) are among the common compounds found in these emissions. In the present study, removal of methanol and n-hexane by biofilteration process was investigated. Chir pine cone nuts were used as filter media. They were inoculated with pseudomonas putida, a gram negative bacteria. Mixture of methanol and n-hexane was passed through the filter media to evaluate the filter efficiency. The biofilter was operated at 25 - 35 °C temperature, air flow rate of 0.35 m^3 h^{-1} and nutrient supply 1-2 L day^{-1}. The maximum removal efficiency for methanol was 93.41 % at an inlet concentration of 80.73 g $m^{-3}h^{-1}$ and the maximum removal efficiency of n-hexane was 48.01 % at an inlet concentration of 181.47g $m^{-3}h^{-1}$. Maximum elimination capacity for methanol was 109.14 g m^{-3} h^{-1} at an inlet loading of 118.18 g m^{-3} h^{-1} and for n-hexane it was 91.06 g m^{-3} h^{-1} at the loading rate of 191.16 g m^{-3} h^{-1}.*

1. INTRODUCTION

The volatile organic compounds (VOCs) emission is a primary contributor of the atmospheric pollution, which results in poor air quality. These pollutants are emitted from chemical, petrochemical allied industries, pulp industries, wood product industries and paint manufacturing industries. VOC emissions originate from loading and breathing losses from storage tanks, venting of process vessels, leaks from piping and equipment, wastewater streams and heat exchange systems. Methanol and alkanes (e.g. n-hexane) are among the common compounds found in these emissions.

Methanol is mostly used as solvents in the production of paints, solvents, varnishes, paint thinners. Methanol is formed in the process of oil and gas extraction and in production of paper and its products, chemicals, motor vehicles along with their parts, wooden products, metals (iron, steel and other non-ferrous metals), food, beverages and meat products. Methanol is the simplest alcohol, and is a light, volatile, colorless, flammable, poisonous liquid with a distinctive odor that is somewhat milder and sweeter than ethanol. Methanol is responsible for accidental, suicidal, and epidemic poisonings that cause death or permanent sequelae.

n-Hexane is a naturally occurring component of crude oil and natural gas and is present in refined petroleum products such as motor fuels. It is released from industries manufacturing, using or handling hexane. Examples include rubber and plastics products industries, oil refineries, chemical plants, footwear manufacturing, petrol, and paints and adhesives. n-hexane is a clear colorless liquid with a petroleum-like odor and vapors heavier than air. Acute (short-term) inhalation exposure of humans to high levels of hexane causes mild central nervous system (CNS) effects, including dizziness, giddiness, slight nausea, and headache.

Pinus roxburghii, also known as chir pine or longleaf Indian Pine. It is mostly found in Himalayan range. It generally occurs at lower altitudes (500-2000 m). It's leaves are needle shaped. The cones of chir pine are ovoid conic, 12-24 cm long and 5-8 cm broad at the base. The cones of chir pine are generally collected for two purposes, collection of seed for reforestation and for decoration. Traditionally, the cones of chir pine are used during the occasion of Dipawali as the firecrackers [3]. Cones can also be used as a fire starter in fireplaces or crushed and moulded into presto-log shapes. In some areas, cones are made into curio items for sale to tourists. The overall objective of the present study was to evaluate performance of a biofilter treating the mixture of methanol and n-hexane.

The main objective of the present study was to remove the mixture of methanol and n-hexane using a culture of bacteria pseudomonas putida grown over the bed of pine cone nuts media in a biofilter.

2. MATERIALS AND MEDIA

2.1. Microorganism: *Pseudomonas putida* (MTCC-102), a heterotrophic isolated bacterial strain was purchased from MTCC Chandigarh, India. The strain was propagated in nutrient broth solution at 28 °C.

2.2. Media: Biofilter was packed with chir pine (*Pinus Roxburghii Sarg)* cone nuts media. The pine cones were obtained from Tehri Garhwal, Uttarakahand and are broken down to get chir pine cone nuts. They were washed and dried in sunlight first. Later, they were dried in the oven. Size of nuts ranged from 1.5 cm to 4 cm. The pseudomonas putida was inoculated in media.

2.3. Biofilter: It consisted of four sections which were attached to each other with the help of screws. Each section has 20 cm height and 9.4 cm inner diameter. High vacuum silicon grease was used to make the biofilter air tight. The total packed bed volume was 4.65 L and total packed depth of bed was 70.5 cm. For measurement of temperature and collecting samples, sampling ports were provided at each section of biofilter. First of all, air from an air pump was passed through an activated carbon filter to eliminate any unwanted contaminants present in the air and then air flow was separated into three streams such that two were having minor flow with the help of hand operated flow splitters. Two rotameters were used to record the air flow rate going to the methanol and n-hexane vessels so that concentration of these compounds in the inlet stream could be controlled. Samples were collected at a regular interval from the inlet, outlet as well as from the sampling ports using an airtight syringe and analyzed for methanol and n-hexane.

2.4. Biofilter operation Details: The biofiltration of air stream containing methanol and n-hexane was carried out from May 3, 2019 to May 31, 2019 at various operating conditions in a down flow mode chir pine cone nuts based biofilter. The concentrations of methanol and n-hexane and flow rate were varied to maintain desired inlet loading rate during the study.

2.5. Analytical Techniques: The concentration of methanol and n-hexane were using Trace 1300 Gas Chromatograph.

3. RESULTS

The results obtained during first phase shows that the maximum removal efficiency for methanol was 93.41 % at an inlet concentration of 80.73 g $m^{-3}h^{-1}$ and the maximum removal efficiency of n-hexane was 48.01 % at an inlet concentration of 181.47g $m^{-3}h^{-1}$. Maximum elimination capacity for methanol was 109.14 g m^{-3} h^{-1} at an inlet loading of 118.18 g m^{-3} h^{-1} and for n-hexane it was 91.06 g m^{-3} h^{-1} at the loading rate of 191.16 g m^{-3} h^{-1}. The treatment of binary mixture of n-hexane and methanol using fungi instead of bacteria are accompanied by high reaction rate constants which ultimately leads to better degradation rates [2]. Elimination capacity obtained in the present study was less than elimination capacity obtained by [1].

[1] reported maximum removal efficiency for methanol as 99.7 % at an inlet concentration of 218.62 g $m^{-3}h^{-1}$ and the maximum removal efficiency of n-hexane was 73.21 % at an inlet concentration of 186.97 $m^{-3}h^{-1}$. Maximum elimination capacity for methanol was 362.96 g m^{-3} h^{-1} at an inlet loading of 481.63 g m^{-3} h^{-1} and for n-hexane it was 136.88 g m^{-3} h^{-1} at the loading rate of 186.97 g m^{-3} h^{-1}. The removal efficiency and elimination capacity obtained by him does not show any constant rise or fall but they randomly increase or decrease without showing any relationship.

The results of variation in inlet concentration, outlet concentration and removal efficiency with time for methanol and n-hexane are shown in Figure 1 and Figure 2, respectively.

The graphical representation of relationship between inlet and outlet concentration of methanol and removal efficiency with operating time has been shown in figure 1 shows that initial removal efficiency was low and gradually it increased and to later become approximately constant. Fluctuations during the initial period arise because biofilter required few days to get stable. Once it got stable, the removal efficiency became almost constant.

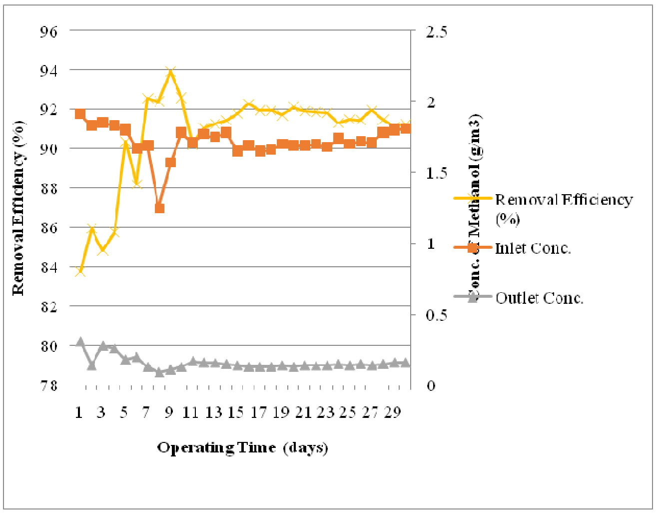

Figure 1: Variation in Inlet Concentration, Outlet Concentration and Removal Efficiency of Methanol with Time.

The graphical representation of relationship between inlet and outlet concentration of n-hexane and removal efficiency with operating time has been shown in figure 2 which indicates that initial removal efficiency was low and gradually, it increased and to later become approximately constant. Since the removal efficiency observed for n-hexane was quite low, the inlet concentration n-hexane was increased to get better results. But it could not produce major difference as removal efficiency did not get much enhanced by this. After few days of operation as the whole system become stable, it started showing almost constant removal efficiency.

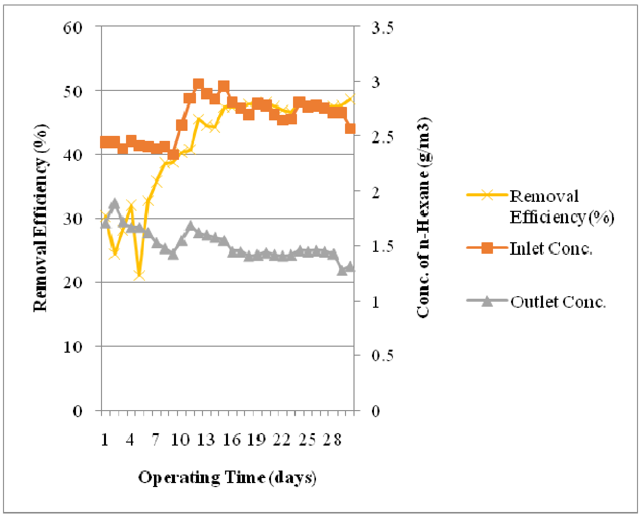

Figure 2: Variation in Inlet Concentration, Outlet Concentration and Removal Efficiency of n-Hexane with Time.

4. CONCLUSIONS

In present study, it has been observed that biodegradation of methanol is much easier than n-hexane by using chir pine cone nuts inoculated with pseudomonas putida. The removal rate of n- hexane is approximately half that of methanol. The maximum removal efficiency for methanol was 93.41 % at an inlet concentration of 80.73 g $m^{-3}h^{-1}$ and the maximum removal efficiency of n-hexane was 48.01 % at an inlet concentration of 181.47g $m^{-3}h^{-1}$. Maximum elimination capacity for methanol was 109.14 g m^{-3} h^{-1} at an inlet loading of 118.18 g m^{-3} h^{-1} and for n-hexane it was 91.06 g m^{-3} h^{-1} at the loading rate of 191.16 g m^{-3} h^{-1}. Results shows that bacterial biofilter was less efficient for the degradation of methanol and n-hexane than fungi biofilter as reported earlier.

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