

# Biofiltration for the Removal of Methyl Isobutyl Ketone (MIBK)

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## Abstract

The biological treatment processes found wide applications in wastewater, air & solid waste pollution control. The need for alternate cost effective treatment technologies led to similar biological treatment processes for waste gas streams. One such treatment technology is biofiltration. Biofiltration technology utilizes the microorganisms to biologically degrade Volatile Organic Compounds (VOCs) and odor contained in waste air streams. In the present study, the culture was developed for the removal of methyl isobutyl ketone (MIBK), which causes adverse effects on health. The microbial culture obtained from Municipal Sewage Treatment Plant, BITS Pilani is acclimatized with MIBK as the carbon source in a mineral salt medium (MSM). The biodegradation of MIBK is studied for a concentration 400 mg/l. The optical density (OD) of microbial culture is obtained. The maximum absorbance value of 0.369 is achieved at 540 nm using U.V. spectrophotometer. The maximum biomass concentration is found to be 257 mg/l.

**Keywords:** Biofiltration; Volatile Organic Compounds (VOCs); optical density; MIBK.

## INTRODUCTION

Volatile Organic Compounds (VOCs) are widely used in many industries such as printing, petrochemicals, plastics, refrigerant, electronics, and paint manufacturing. However, large quantities of VOCs are released into the air, soil and groundwater because of occasional accidents and the absence of proper treatment technologies. Most VOCs are toxic and carcinogenic substances. Loss of these substances to the ambient air may have an adverse impact on air quality and thus endanger public health [1]. Therefore, it is very important to develop effective means of removing these compounds to preserve human health and the environment.

Bulk organic chemicals such as MIBK and Methyl Ethyl Ketone (MEK) are used as solvent in many process industries [1, 2]. The primary sources of MIBK are the industries that manufacture it or use it in production. Some of the industries that use it in production are chemical industry, rubber manufacturers, pharmaceutical industry, the semiconductor industry, and the manufacturers of paints, varnishes and lacquers. Workers in the industries that use or produce MIBK are at risk of exposure. Breathing MIBK for short periods of time (i.e. painting in a poorly ventilated area) can affect the nervous system. The effects may be headaches, dizziness, nausea, numbness in the fingers and toes, and unconsciousness and even death (if the exposure is prolonged). MIBK vapor irritates the eyes, nose, and throat. Prolonged contact with the skin will cause irritation. Therefore, MIBK has been designated as high priority toxicity chemicals [3, 4].

Physical and chemical methods such as incineration, ozonation, combustion, and adsorption, are expensive and require elaborate equipment and/or fuel. These processes also generate secondary pollutants that require further treatment because they simply convert target material into another phase [1]. Compared to the above conventional processes, biofiltration is a very cost-effective process that degrades VOCs to non-toxic materials such as carbon dioxide (CO<sub>2</sub>), water (H<sub>2</sub>O) and biomass which can be used as manure. The microbes take the VOCs as the carbon source (food) for their growth and hence do not cause any sludge handling problem. Therefore, there is no need of any secondary treatment process.

Biofiltration is a technology, which is used for the treatment of gas streams contaminated with biologically degradable compounds [5]. Biofilters are those bioreactors in which a mixed culture is attached to a stationary support material such as compost, soil, peat, granular activated carbon or other porous media capable of adsorbing gaseous compounds and support biological growth. Contaminants pass into a wet biofilm layer surrounding the support particles and are aerobically

degraded to carbon dioxide and water. The bed's moisture is maintained at constant level by introducing humid air to maintain a biologically active layer surrounding the media which is known as "biofilm". VOCs streams containing airstreams are transported to the air/biofilm interface where VOCs are adsorbed by biofilm and used as carbon / or energy sources by microorganisms.

The ketones are not so far extensively studied as far as biodegradability is concerned. Aerobic biodegradation tests have shown that, it is in general relatively easily biodegraded [6, 7]. In the present study, the biodegradability of MIBK was established by carrying out a wide range of batch experiments. The final well acclimatized culture with MIBK was prepared from the microbial culture obtained from the Municipal Sewage Treatment Plant, BITS Pilani. The batch biodegradation of MIBK was studied and biomass concentration was obtained for a concentration of 400 mg/l in 250 ml Erlenmeyer flasks. The optical density (OD) of microbial culture was obtained using UV Spectrophotometer.

## **MATERIALS AND METHODS**

### **Materials**

MIBK and other chemicals were used which were of Merck grade. The 250 ml Erlenmeyer flasks were used for carrying out the experiments.

### **Preparation of Media**

The media, Mineral Salt Medium (MSM) was prepared which had the following composition (in g/l):  $K_2HPO_4$  – 0.8,  $KH_2PO_4$  – 0.2,  $CaSO_4 \cdot 2H_2O$  – 0.05,  $MgSO_4 \cdot 7K_2O$  – 0.5,  $(NH_4)_2SO_4$  – 1.0,  $FeSO_4$  – 0.01 in distilled water. 100 ml of MSM was taken in 250 ml Erlenmeyer flask and autoclaving was carried out to make it free from all the impurities. Stock glucose solution was prepared by dissolving 10 g of glucose in 100 ml distilled water.

### **Microorganisms Culture**

The microbial mixed culture was obtained from the Municipal Sewage Treatment Plant, BITS Pilani and acclimatized with MIBK as the carbon source in a MSM. The sludge was kept for settling for almost 3-4 hours in cool place (away from sunlight). 10 gm of settled sludge was taken and was thoroughly mixed with 100 ml of distilled water. The shaking was carried out gently and then sludge was allowed to settle. The 50 ml of supernatant was taken and centrifugation was carried out for 2 minutes at 10,000 rpm in the Centrifuge. The pellet achieved after the centrifugation was further used for the microbial growth and supernatant was discarded.

### **Immobilization Procedure**

The immobilization was carried out in laminar hood chamber. The autoclaved MSM solution was added with 1 ml of 1000 ppm glucose solution. Then 1  $\mu$ l of MIBK was added to maintain 9 ppm concentration of MIBK. After that, a loop full of sludge which was obtained after centrifugation was added. The solution was then kept in the rotary shaker at 37<sup>o</sup> C for around 48 hours. After obtaining sufficient microbial culture, the glucose utilizing culture was acclimatized with MIBK by slowly increasing its concentration and decreasing the concentration of glucose in the mixture. This was carried out by a series of transfers at 48 hour intervals for a period of more than 3 weeks to obtain a final well acclimatized mixed culture grown in MIBK. The MSM solution was prepared fresh for carrying out each transfer after every 48 hours. The final microbial culture obtained was containing the microorganisms trained with MIBK

### **Batch Experiments**

To obtain the optical density of microbial culture, prepared from the culture obtained from the municipal sewage treatment plant, 100 ml of MSM solution was autoclaved and added with 1 ml of stock solution of glucose to maintain the glucose concentration of 1000 ppm in the solution. Then a loop full of sludge was added. The solution was then kept in the rotary shaker at 37<sup>o</sup> C. The absorbance of this solution was measured after every 24 hours for the period of 7 days.

The batch experiments were carried out for the measurement of biomass concentration and biodegradation of MIBK. This study was carried out for a concentration of 400 mg/l of MIBK in 250 ml Erlenmeyer flasks. In these experiments, 100 ml of MSM was prepared and autoclaved to remove impurities. This MSM solution was added with 46  $\mu$ l of MIBK to maintain 400 mg/l concentration and was inoculated with 5 ml of pre-cultured suspension. Then it was kept in a rotary

shaker at 150 rpm at 37<sup>0</sup> C. Flask was sealed with stopper to minimize VOCs loss. Samples collected at regular intervals were analyzed for biomass and residual MIBK concentration. The culture was passed through a filter. The filter was dried at 90<sup>0</sup> C for 6 hours and cooled in a dessicator prior to weighing.

The concentrations of MIBK in aqueous samples were determined by using a Model 5700 series gas chromatograph (Nucon Engineers) fitted with 2 m long stainless steel column with a poropak packing and a flame ionization detector. The injection port was maintained at 150<sup>0</sup> C, detector port at 150<sup>0</sup> C and oven temperature was maintained at 200<sup>0</sup> C. Nitrogen was used as the carrier gas. Injections of known volumes of MIBK which varied from 1 to 5  $\mu$ l were introduced manually to obtain the calibration plot. Then concentration of residual MIBK which was collected at different intervals was analyzed by using gas chromatograph with help of calibration plot.

## RESULTS AND DISCUSSION

### Optical Density (OD)

The OD of the microbial culture was measured at 540 nm in 10 mm cuvette with a model 119-Systronics UV-VIS Spectrophotometer with respect to distilled water. The maximum absorbance value of 0.369 was achieved at 540 nm after 1 day. This shows that MIBK and glucose of amounts mentioned above was consumed by mixed culture in 1 day.

### Biomass Concentration

Culture dry weights were obtained to calculate the value of biomass concentration. Biomass concentration was obtained for microbial culture in aerobic environment showing three phases. Fig. 1 shows the variation of biomass concentration with time. It can be categorized into three phases such as lag, log and stationary phase. Initially, there was no increment in the biomass concentration with time giving the lag phase. In log phase, concentration of biomass was increased with time and after sometime (in stationary phase) there was no increment in biomass concentration. The maximum biomass concentration was found to be 257 mg/l. The lag phase was observed up to 4 hours and corresponding biomass concentration was 60 mg/l. The log phase was observed up to 8 hours and biomass concentration was found to be increased to 240 mg/l. After that, the stationary phase was observed from 8 to 12 hours and corresponding biomass concentrations was found to be 257 mg/l. Fig. 1 show that after 8 hours there was no increase in biomass concentration which indicates that MIBK (400 mg/l) was consumed completely by microbial culture. After that, there was no increase in biomass concentration because of the non-availability of the carbon source. The experimental result obtained validated the biodegradability of MIBK as mentioned in the literature [3, 8].

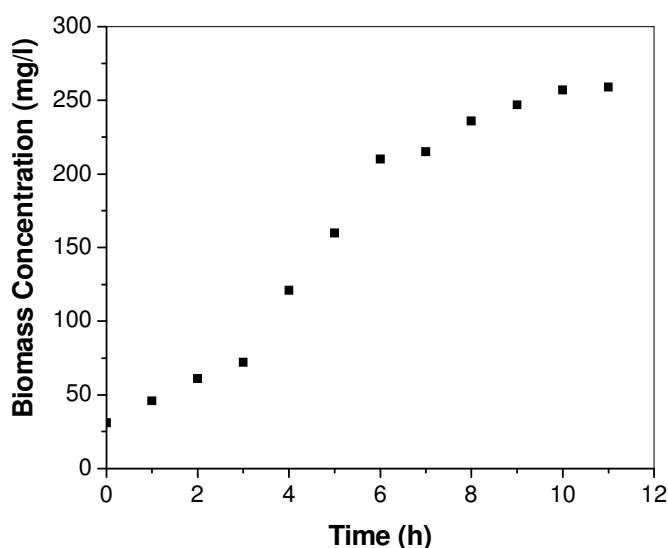


Fig. No. 1: Biomass Concentration (mg/l) Vs Time (h)

### Dissolved Ketone Analyses

Fig. 2 shows the calibration plot for MIBK concentration in aqueous phase. Fig. 3 was plotted between concentration of MIBK and time. In the Fig. 3, it was observed that the initial concentration of MIBK was more than 400 mg/l. It was because of the presence of MIBK in precultured solution. The MIBK concentration was found to be decreasing from 400 to 10 mg/l in 10 hours. It shows that the 400 mg/l of MIBK was completely consumed by microorganisms within 10 hours. That means the biodegradability was found to be good.

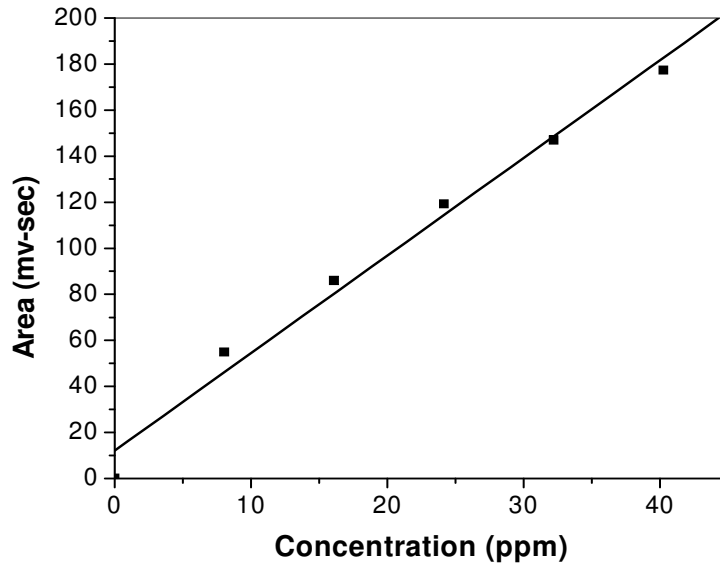


Fig. No. 2: Calibration Plot for MIBK

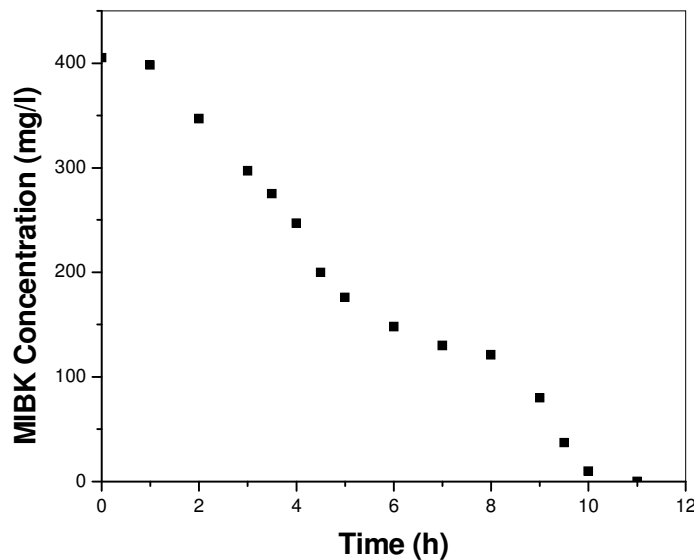


Fig. No. 3: MIBK Concentration (mg/l) Vs Time (h)

## CONCLUSIONS

The present study has shown that the concentration of biomass increases with time and then becomes constant showing that growth stops once the substrate (MIBK in this case) is consumed completely. It also concludes that the microbes take some time to acclimatize to the new environment. The growth of the microbial culture follows the lag, log and stationary phases and the batch studies carried out for MIBK biodegradation has also followed the same growth curve. The MIBK concentration was found to be 10 mg/l from initial concentration of 400 mg/l showing that biodegradation of MIBK has taken place by the acclimatized mixed culture. The performance of cultures needs to be understood well in order to carry out the further detailed studies. The results obtained were matching with those available in the literature.

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