# ABSTRACT

Among various chemical, physical and biological processes used for treatment of gaseous waste stream biotiltration has been proved to be a promising option from economical as well as ecological point of view particularly for removal of VOCs at high volume and low level of concentration.

In the biofiltration process the role of support media is most crucial. In the past, a number of bio filtration studies have been reported in literature using natural and synthetic materials like compost, peat, bark, wood chip, coal, plastic pall rings, activated carbon (GAC), polyurethane foam etc. as packing media. There are certain advantages and disadvantage of each packing media. Although natural packing media exhibits excellent performance due to better adaptability of microbial system and inherent availability of many macro and micro nutrients but during the long-term operation of biofilter column, natural packing materials like compost, agro waste, peat, soil etc. usually crack causing medium compaction which results in the rise in the bed head loss. In order to prevent such problems, mechanically strong non-biodegradable media should be used. Inert materials like PU-foam, GAC etc. are mechanically strong but usually require a continuous supply of macro and micro nutrients during the operation of biofilter column and thus make the operation more expensive.

One of the promising options is to improve the durability, strength and other drawbacks of natural materials by physic-chemical treatment and thus make it efficient for biofilter operation. Keeping this fact in mind, present work has been planned with following objectives.

i. To modify the physical strength, durability and nutrient release capability of easily available exhaustly tested natural and low cost materials such as wood charcoal and compost for biofilter applications.

ii. To characterise the modified biofilter media.

iii. To evaluate the performance of modified media against VOCs laden air stream supplied to the biofilter column for the prescribed period of time for changing the inlet concentration of VOCs and inlet flow rate.

iv. To study the kinetics of biodegradation of VOCs in the biofilters.

## 2. Experimental

In the present work wood charcoal and compost were used as base material because these materials have already shown very good performance for the removal of VOCs in the biofilters. A few limitations of biofilters packed with these materials are strength, durability and medium compaction with respect to time. These materials also require continuous supply of some of the essential macro and micro nutrients.

In the process of modification, the base materials were mixed with PVA, macro-nutrients (N, P, and K) and salts of micro-nutrients. The role of PVA is to provide strength and to bind the added macro and micro nutrients. The four modified biofilter media as mentioned below were prepared in the present study and tested against various VOCs.

1. PVA/Compost /$KNO_3$ Composite beads for the biodegradation of BTX.
2. PVA/Compost /$KNO_3$ Composite beads for the biodegradation of styrene.
3. PVA/Woodcharcoal /$KNO_3$ Composite beads for the biodegradation of MTX.
4. PVA/ (Compost+Woodcharcoal) /$KNO_3$ Composite beads for the biodegration of styrene.

The modified media were packed in the biofilter columns and tested for biodegradation of most commonly used VOCs under ambient condition with variation in concentration and flow rate. All experiments were conducted under ambient condition and without supply of the nutrient. Sometimes only water was supplied to maintain sufficient moisture in the bed. The results are presented and discussed in the subsequent sections.

## 3. Results

### 3.1 Biodegradation of vapour phase Benzene, Toluene and Xylene (BTX) using PVA/Compost/KNO3 Composite beads

The microbial inoculum culture was obtained by acclimating the activated sludge taken from the local wastewater treatment plant. Glucose supply (5 g/day) was added to the suspension during the initial phase of acclimation, but was gradually replaced by mixture of BTX as the only carbon source. This whole long process increased the colony of desirable VOCs degrading microorganism in the mixture. Bed porosity, moisture retention capacity, dry weight of the modified biofilter media were measured and found to be 81%, 68.3%, 67% .CHN content was found to be 28.69%,1.83%,3.2% respectively. The continuous biodegradation of Benzene, Toluene and Xylene vapours were carried out for a period of 57 days in three distinct phases without supply of nutrient. The maximum removal efficiency of 96.80, 97.50 and 94.5% were achieved on 29$^{th}$ day of operation for benzene and toluene and on 27 $^{th}$ day of operation for xylene. The maximum elimination capacities of all three components of BTX mixture were found to be 388.33, 327.73 and 276.84 g $m^{-3}$ $h^{-1}$ at inlet loading rates of 477.36, 439.02, and 376.65 g $m^{-3}$ $h^{-1}$ respectively. The value of $EC_{max}$ was found to be 0.218, 0.255, 0.123 g $m^{-3}s^{-1}$ for benzene, toluene and xylene respectively. Similarly, the value of *K*s was 1.72, 2.21, 0.79 g $m^{-3}$ respectively. During whole operation, the bed temperature was always found higher then inlet stream temperature. Variationsin inlet stream temperature and bed temperatures were found in the range of 26.8-31.2 and 28.9-36.2$^{o}$C, respectively. The higher value of bed temperature indicates exothermic nature of bioreactions in the biofilter. During whole operation only small fluctuation in the pH(6.95-7.28) of the lechate was observed. Relative humidity of inlet stream was found in the range of 87-95%. and pressure drop across the bed was found to be 4-6 mm water/unit bed length during the whole experiment.

### 3.2 Biodegradation of vapour phase Methyl ethyl ketone, Toluene and Xylene (MTX) using PVA/ Wood Charcoal /KNO3 Composite beads

Method of preparation of inoculum and its acclimation was same as used in above experiment. Bed porosity, moisture retention capacity, dry weight of the modified biofilter media were found to be 77%, 82.8%, 0.47 CHN content was found to be 68.6%, 3.65,2.29% respectively. Continuous biodegradation of MEK, Toluene and Xylene vapours were carried out for a period of 56 days in three distinct phases. The maximum removal efficiency of 96.35, 97.87 and 95.2% were achieved on $18^{th}$ day of operation for each components. The maximum elimination capacities of all three components of MTX mixture were found to be 182.53, 313.39 and 232.96 g $m^{-3}$ $h^{-1}$ at inlet loading rates of 229.43, 371.67, and 332.75 g $m^{-3}$ $h^{-1}$ respectively. The value of ECmax was found to be 0.13, 0.16, 0.099 m-$^{3}$ $gs^{-1}$ for methyl ethyl ketone, toluene and xylene respectively. Similarly, the value of *K*s was 1.49, 1.71, 0.63 g $m^{-3}$ respectively. No significant variation in the pressure drop across the bed was observed during whole operation. During whole operation inlet stream and bed temperature variations were found in the range of 24.5 - 33.2 and 25.9 - 34.3$^{o}$Crespectively. Bed temperature was always found more than the temperature of inlet stream which might be due to exothermic bioreaction in the biofilter. The pH of the lechate was found almost constant (6.93 - 7.02) and this may be due to the buffer capacity of phosphate solution in which the composite beads were immersed during the preparation. Relative humidity of inlet stream was found in the range of 80-95%.

### 3.3Biodegradation of styrene PVA/ (Wood Charcoal +compost)/KNO3 Composite beads

Method of preparation of inoculum and its acclimation was same as used in above experiment. Bed porosity, moisture retention capacity, dry weight of the modified biofilter media were found to be 80 %, 85.6%, 0.37. CHN content was found to be 44.54%, 5.20%, 1.63% respectively. The continuous biodegradation of styrene vapour was carried out for a period of 131 days divided into five distinct phases. The maximum removal efficiency of 97.3 % was achieved at inlet concentration of 2.28 g $m^{-3}$ with

loading rate of 522.5 g $m^3$ $h^{-1}$. Maximum value of elimination capacity was obtained 870 g $m^{-3}$ $h^{-1}$ at an inlet load of 990 g $m^{-3}$ $h^{-1}$. SEM images of modified wood charcoal and compost composite beads before and after acclimation period clear there was no growth before acclimation and after acclimation, rod shape bacteria was formed on the surface of biofilter media containing a biofilm. Some fungi growth was also visible on the surface. Pressure drop across the bed during whole operation was observed in the range of 5-7 mm of water column. During whole operation, temperature of inlet stream and bed temperature were found in the range of 26.5 - 31.2 and 28.9 - 36.3$^oC$ respectively. Bed temperature was always found more than the temperature of inlet stream which might be due to exothermic bioreaction in the biofilter. Small fluctuation in the pH of the leachate was found (6.80 - 7.07). Relative humidity of inlet stream loaded with styrene vapour was found in the range of 83 - 94%. Without external supply of nutrient solution high removal of styrene was observed in the bio filter using modified media.

**3.4Biodegradation of styrene PVA/ (Compost)/KNO3 Composite beads**

Method of preparation of inoculum and its acclimation was same as used in above experiment. Bed porosity, moisture retention capacity, dry weight of the modified biofilter media were found to be 82.4 %, 66.5 %, 076. CHN content was found to be 27.43 %, 1.88 %, 2.87 % respectively. The biodegradation of styrene vapour was carried out for a period of 123 days divided into four distinct phases. Maximum removal efficiency of 98.2% was achieved at inlet concentration of 2.27 g $m^{-3}$ with loading rate of 520.2 g $m^3$ $h^{-1}$.Maximum value of elimination capacity was obtained to be 870 g $m^{-3}$ $h^{-1}$ at an inlet load of 980.9 g $m^{-3}$ $h^{-1}$. The value of ECmax and *K*s were found to be1139.24 g $m^{-3}$ $hr^{-1}$ and 1.77 g $m^{-3}$ for styrene. Pressure drop across the bed during whole operation was observed in the range of 3-8 mm of water column. During whole operation, temperature of inlet stream and bed temperature were found in the range of 27.5 - 33.2 and 30.8 - 37.5$^oC$ respectively. The pH of the lechate was found fluctuating in the range of 6.9 - 7.4.Relative humidity of inlet stream was found in the range of 83 - 91%.

## 4. Conclusions

I. Modified biofilter media was found effective for long term operations without supply of nutrients.

II. In all cases, the modified media shown good results under high as well intermittent loading conditions.

III. In all cases, negligible pressure drop was found in the biofilter media and $p^H$ was found fluctuating within a narrow range.

IV. In all cases, kinetic study found that the ECmax obtained by the model is greater than the experimentally found ECmax suggesting that with optimizing the various physical and biochemical parameters in the biofilter one can get more elimination capacity.

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