6. BIODEGRADATION OF STYRENE FROM AIR USING MODIFIED COMPOST COMPOSITE BEADS AS BIOFILTER MEDIA

In the first two experiments modified modified compost and wood charcoal were tested against common VOCs and results in both cases were quite promising. However compost based modified media provided better results in terms of elimination capacity and removal efficiency which is most important performance parameter in the biofilter operation. The only advantage of wood charcoal based media was lower acclimation time. On the basis of results of first two experiments it was decided to carry further experiments using modified media based on compost and compost+woodcharcoal on a VOC which is tough to degrade. The styrene is selected as targeted VOC for next two experiments.

6.1 Preparation of PVA/ (compost)/KNO3 Composite beads

Compost (200 g) was slowly mixed into an aqueous solution (800 ml water mixed with 128 g KNO_3) in a 2000 ml bucket. Now, this mixture was sealed and kept for approximately 24 h for the compost to adsorb KNO_3. An aqueous solution (2000 ml water mixed with 128 g KNO_3) was prepared and PVA powder (200 g) was added toit.This mixture was heated to 90^0C. The Compost/KNO_3 mixture was slowly added to the PVA/KNO_3 mixture at 90°C to dissolve the entire components properly. The final PVA/compost/KNO_3 mixture was stirred for 1.5 h at 90°C and then cooled to 40°C. 6% boric acid aqueous solution (1500 ml) was now prepared and used to drip the previous mixture leading to the formation of beads. A phosphate aqueous solution was prepared with 150 g $NaH_2PO_4.2H_2O$ and 335 g $Na_2HPO_4.12H_2O$ in 450 ml water then, the beads were transferred into the phosphate aqueous solution and stirred for 30 min.The beads were dried in anoven at 100°C for 36 h and then immersed in the 0.384M KNO_3 solution. Finally, the beads were stored in a desiccator at room temperature. Bed porosity, dryweight and water retention capacity was measured using theconventional method of analysis. CHN content of composite bead was measured using CHN analyzer (Perkin Elmer).Physiochemical characterization results of modified media are given in Table6.1.

6.2 Result and Discussions

6.2.1 Physicochemical characterization results

Physicochemical characterization results indicated that the prepared media has desirable properties such as low density, high porosity, high moisture content etc. as required for successful biofiltration (Table 6.1).

Table 6.1: Physico-chemical characteristics of (PVA/Compost/KNO_3) composite bead.

Sl. No.	Parameters	Composite bead
1.	Particle size (mm)	6-8
2.	Bed porosity,%	82.4
3.	Moisture retention capacity, %	66.5
4.	Dry weight,%	0.76
5.	C H N Content % C H N	27.43 1.88 2.87

6.2.2 Biodegradation of Styrene

The biodegradation of styrene vapour was carried out for a period of 123 days divided into four distinct phases as shown in Table 6.2. During the start-up, the biofilter was operated with an initial flow rate of 0.06 m^3 $h^{-1}$for 33 days with inlet concentration ranging from 0.21-1.55

g m^{-3}.The results are presented in Figure.6.1. Removal efficiency increased slowly and after 24th day of operation, it became almost constant to 91 %, which is anindication of steady state condition in the biofilter. During phase I, theflow rate was increased to 0.12 m^3 h^{-1} corresponding to an EBRT of 23.5 sec. with the variation of inlet concentration in the range of 1.55 to 2.39 g m^{-3}.No significant variation of removal efficiency was observed in the biofilter in this phase and it was mostly found in the range of 92-96 %.In phase II, theflow rate was again raised from 0.12 to 0.18 m^3 h^{-1}(EBRT of 15.6 sec) and inlet concentration of styrene was varied in between 1.59-3.18 g m^{-3} and the maximum removal efficiency of 98.2% was achieved at inlet concentration of 2.27 g m^{-3} with aloading rate of 520.2 g m^3 h^{-1}. Removal efficiency reduced to 85.8 % with afurther increase in inlet concentration. Flow rate was further increased to 0.24 m^3 h^{-1} with anEBRT of 11.77 sec for Phase III with inlet concentration ranging from 2.30 -3.58 g m^{-3}. In this phase low removal efficiency of 77.65% was obtained corresponding to thehigher concentration of styrene and the possible reasons for thedecline in removal efficiency might be low residence time of pollutants and development of toxic conditions for the biodegradation at such high loading (Rene et al., 2005).

Table 6.2- Operating conditions of each phase in the bio filter experiments for Styrene.

Nature of biofilter operation	Operation days	Flow rate (m^3 h^{-1})	EBRT (sec)	Inlet concentration range (g m^{-3})
Acclimation phase	0-33	0.06(1LPM)	47.1	0.21– 1.55
Phase I	34-69	0.12(2LPM)	23.5	1.55-2.39
Phase II	70-96	0.18(3LPM)	15.6	1.59-3.18
Phase III	97-123	0.24(4LPM)	11.77	2.3-3.58

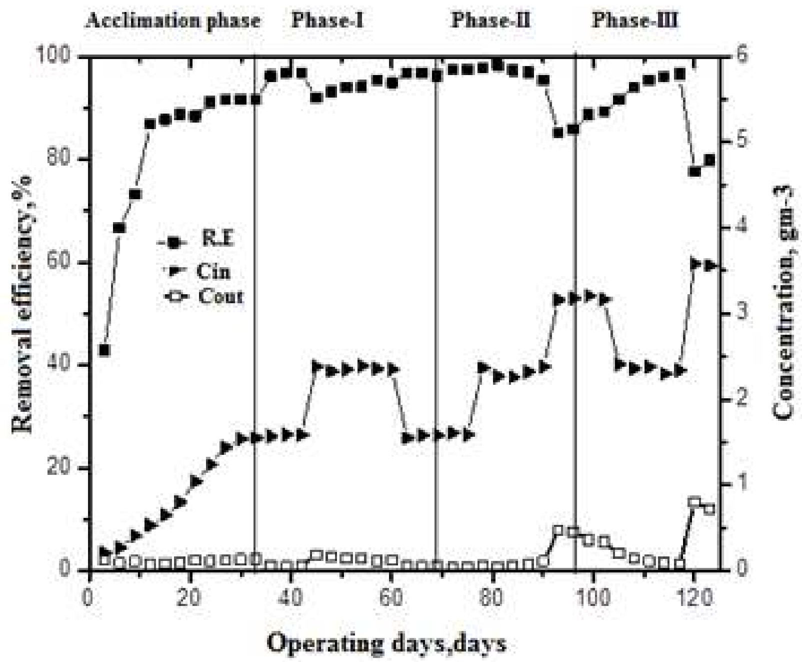

Fig.6.1: Variation of RE with achange in inlet concentration of styrene with operating days.

6.2.3 Effect of Inlet Loading Rate on Removal Efficiency and Elimination Capacity

Variation of RE and EC with respect to inlet loading rate is shown in Figure6.2. During the whole experimental period, inlet loading rate of styrene was varied in the range of 16.04 to 1093.9 g m^{-3} h^{-1}. Up to the loading rate of approximately 724.2 g m^{-3} h^{-1}, the RE was almost constant and then decreased and this phenomenon may be due inability of the biofilm to degrade the styrene at high loading rates.

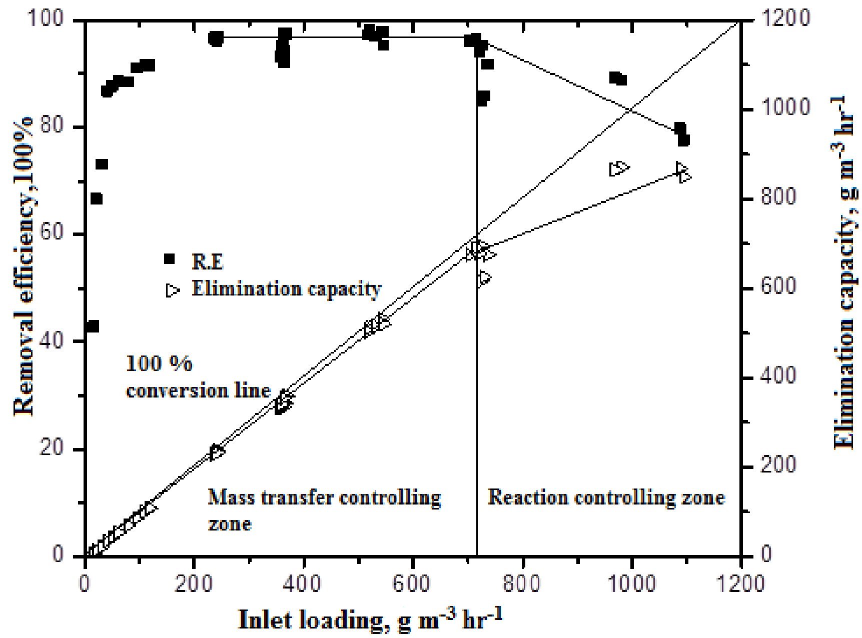

Fig.6.2: Variation of removal efficiency, elimination capacity with inlet load of styrene

A nearly linear relationship between inlet loading and elimination capacity up to the loading rate 724.2 g m^{-3} $h^{-1}$was observed after that RE declined with increase in loading (Figure 6.2).Many researchers have attributed this trend to change in controlling mechanism from diffusion to reaction at higher loading rates of the contaminant (Singh R.S *et al*.,2006;Singh K *et al*., 2010) At the loading rate of 724.2 g m^{-3} h^{-1} the controlling mechanism is changing from mass-transfer to bioreaction. Beyond this value, the elimination capacity increased with slow rate and reached to its maximum value of 870 g m^{-3} h^{-1} at an inlet load of 980.9 g m^{-3} h^{-1}. Similar behaviour is also observed by other researchers (Singh *et al*., 2010, Elmrini*et al*., 2004).

6.3 Kinetic Analysis

The value of ECmax and *K*s (Figure 6.3) were found to be1139.24 g m^{-3} hr^{-1} and 1.77 g m^{-3} for styrene. In calculation correlation coefficient (R^2) was more than 0.95.It has been found that the ECmax obtained by the model is greater than the experimentally found ECmax (870.8 g

m^{-3} $h^{-1)}$, suggesting that with optimizing the various physical and biochemical parameters in the biofilter one can get more elimination capacity. The ECmax and Ks values reported for MEK, toluene, benzene and xylene for MTBX biofiltration in the study was done by Mathur and Majumder (2008) were 306, 118.8,576 and 86.4 g m^{-3} h^{-1}, and K_S values were calculated as 1.785, 0.736, 2.305 and 0.679 gm^{-3}, respectively which are comparable to the values obtained in this work.

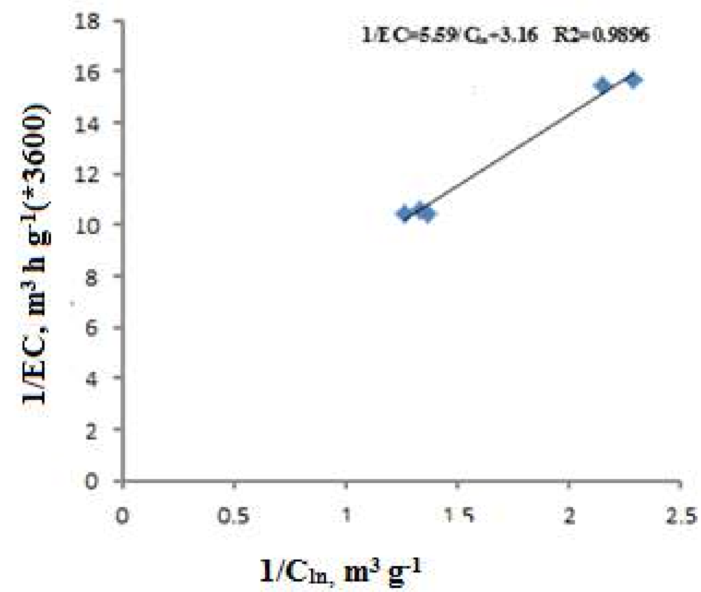

Fig.6.3: Determination of Michaels–Menden kinetic constants for styrene

In the present study, biodegradation of styrene in the biofilter packed with compost modified biofiltermedia was found to be very efficient without a supply of nutrients for 123days of operation. Characterization results of the media showed that it has most of the favourable properties required for biofiltration.The maximum removal efficiency of 98.2 % was obtained at the styrene loading of 520.2 g m^{-3} h^{-1}.The maximum elimination capacity of 870.8 g m^{-3} $h^{-}$was obtained at the styrene loading of 980.9 g m^{-3} h^{-1}.Michaelis-Menten kinetic constantsECmax and

*K*s were also estimated and found to be1139.24 $gm^{-3}hr^{-1}$ and 1.77 g m^{-3} for styrene. Low variation of pressure drop across the bed, negligible change in pH of the leachate was found and also bed temperature was always found more than inlet stream temperature which indicative of heat of exothermicity in the biofilter.The pressure drop across the bed during the whole operation was observed in the range of 3-8 mm of the water column. During the whole operation, the temperature of inlet stream and bed temperature were found in the range of 27.5 - 33.2 and 30.8 - 37.5^{o}C respectively. The pH of the leachate was found fluctuating in the range of 6.9 - 7.4.Relative humidity of inlet stream was found in the range of 83 - 91%.

*****