# 7. BIODEGRADATION OF STYRENE FROM AIR USING MODIFIED WOOD CHARCOAL AND COMPOST COMPOSITE BEADS AS BIOFILTER MEDIA

On the basis of results of previous experiments it was decided to prepare a media containing inherent properties of wood charcoal and compost both and test on a VOC which is tough to degrade. So, in the present experiment composite beads of wood charcoal and compost was prepared and tested in bifilter against styrene as targeted pollutant.

## 7.1 Preparation of PVA/ (Wood Charcoal +compost)/KNO3 Composite beads

The methods of preparation of composite beads are similar to themethod adopted by Chan and Lin (2006). Wood Charcoal (100 g) (6-8 mm) and compost (100g) were dried at 90°C.An aqueous solution of 800 ml water mixed with 128 g $KNO_3$ was prepared in a 2000 ml bucket. Then wood charcoal and compost were added slowly into the aqueous solution. This mixture was sealed and kept for approximately 24 h so that $KNO_3$ get absorbed on the charcoal and compost. Now, 128 g KNO3 and 200 g PVA powder were added into2000 ml water and heated to 90°C for dissolution. Now, the (Charcoal + Compost)/$KNO_3$ mixture was slowly added to the PVA/$KNO_3$ mixture at 90°C. After that, the PVA/(Charcoal + Compost)/$KNO_3$ mixture was stirred for 1.5 h at 90°C and cooled to 40°C. The mixture was slowly dripped into a 6% aqueous boric acid solution (1500 ml) for 60 min leading to the formation of beads. The beads were subsequently transferred into the phosphate aqueous solution and stirred for 30 min. The 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. Finally, the beads were dried in anoven at 100°C for 24 h and then immersed in the 0.384M $KNO_3$ solution again because some amount of water soluble nitrogen may be dissolved out in boric acid solution. Finally, beads were dried and stored in a desiccator at room temperature for use. Physicochemical characterization of the modified media

was carried out and results are given in Table7.1. Bed porosity, dry weight and moisture retention capacity of composite beads were estimated using theconventional method of analysis. CHN content of composite bead was measured using CHN analyser (Perkin Elmer).

## 7.2 Result and Discussions

### 7.2.1 Physicochemical characterization results

Physicochemical characterization results indicated that the prepared media has desirable properties such as high porosity, high moisture content etc. required for successful biofilter operation (Table 7.1).

**Table 7.1:**Physicochemical characteristics of PVA/Charcoal + Compost /$KNO_3$ composite beads composite beads.

| Sl. No. | Parameters | Coal+compostcomposited beads |
|---|---|---|
| 1. | Particle size (mm) | 10-12 |
| 2. | Dry weight(g) | 0.37 |
| 3. | Moisture retention capacity (%) | 85.6 |
| 4. | Bed porosity (%) | 80 |
| 5. | C H N Content (%)<br>C<br>H<br>N | <br>44.54<br>5.20<br>1.63 |

### 7.2.2 Continuous Biodegradation of Styrene Vapour Mixture

The continuous biodegradation of styrene vapour was carried out for a period of 131 days divided into five distinct phases as shown in Table 7.2. During the start-up, the biofilter was

operated with an initial flow rate of 0.06 $m^3 h^{-1}$ corresponding EBRT of 47.1 sec with an average inlet concentration ranging from 0.23 to 1.59 g $m^{-3}$ for 25 days. In this phase, low flow rate and concentrations of the pollutants were kept to provide sufficient microbial growth in the biofilter. The results are presented in Figure 7.1. In this phase removal efficiency gradually increased and stabilized around 95 %. The maximum removal efficiency of 96.2 % was achieved on the25th day of operation and at an inlet load of 121.4 $gm^{-3}hr^{-1}$.

**Table 7.2:** Operating conditions of each phase in the biofilter 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 | 3-25 | 0.06(1LPM) | 47.1 | 0.23– 1.59 |
| Phase I | 26-51 | 0.12(2LPM) | 23.5 | 1.58-2.41 |
| Phase II | 52-71 | 0.18(3LPM) | 15.6 | 1.61-3.22 |
| Phase III | 72-91 | 0.24(4LPM) | 11.77 | 2.32-3.60 |
| Shutdown period | 92-107 | 0.12(2LPM) | 23.5 | 0 |
| Phase IV | 108-131 | 0.18(3LPM) | 15.6 | 1.59-3.29 |

In this phase (acclimation period) more than 90% removal efficiency of styrene was achieved on the13$^{th}$ day of operation and finally became almost constant (95 %), which indicate 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. The inlet concentrations of styrene vapourwere varied in the range of 1.58 to 2.41 g $m^{-3}$ but the removal efficiency was observed almost unaffected by

achange in inlet styrene concentration. The removal efficiency was mostly above 90% with amaximum of 96.8 % achieved on the31$^{th}$ day at the concentration of 1.61 g $m^{-3}$. In phase II, theflow rate was again raised from 0.12 to 0.18 $m^3$ $h^{-1}$ corresponding to EBRT of 15.6 sec. In this phase the inlet

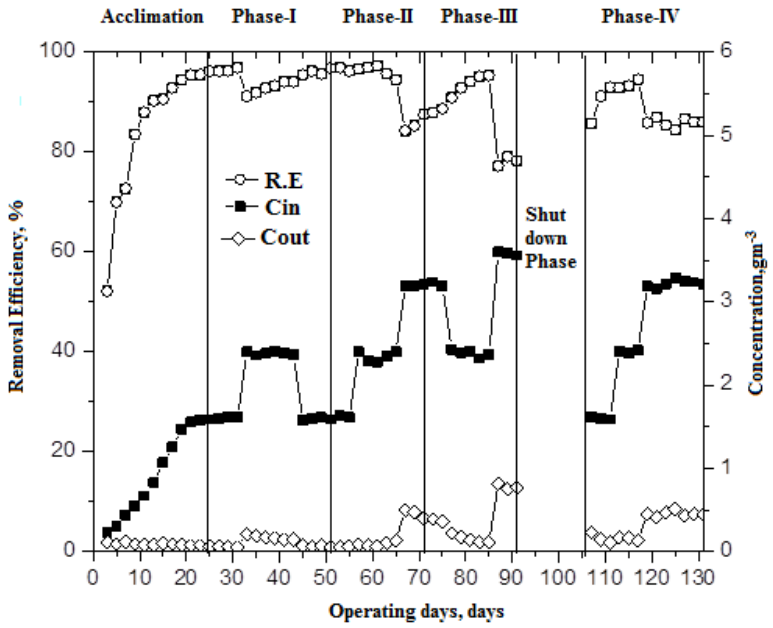


**Fig.7.1:** Variation of RE with achange in inlet concentration of styrene with operating days.

Concentrations of styrene were varied between1.61-3.22 g $m^{-3}$ and the maximum removal efficiency of 97.3 % was achieved at inlet concentration of 2.28 g $m^{-3}$ with aloading rate of 522.5 g $m^3$ $h^{-1}$. Further increase in inlet concentration, a reduction in RE was observed. For phase III, theflow rate was further increased to 0.24 $m^3$ $h^{-1}$ with an EBRT of 11.77 sec and the concentration range was 2.32-3.60 g $m^{-3}$. In this phase low removal efficiency of 77.2% was observed due to low EBRT or low contact time and high inlet concentration of styrene vapour. To check theperformance of biofilter under intermittent loading conditions, it was shut down for 14 days (after phase III) with asupply of air at the rate of 0.12 $m^3$ $h^{-1}$ to maintain anaerobic

condition in the biofilm. After shutdown period, the biofilter was restarted (Phase IV) under the condition almost similar to Phase II (flow rate of 0.18 $m^3$ $h^{-1}$) to know the behaviour and degradation capacity of biofiltration after shutdown. In this phase, the removal efficiency was quickly build up and varied in the range of 84-94 %. At the end of this phase, removal efficiency was stabilized around at 85%. The results show that the biofilter quickly responded for change in flow rates and inlet concentrations, which indicates the presence of active biofilm in the biofilter even after shutdown period. The biofilter operated successfully without asupply of nutrient solution during thewhole experimental period.

### 7.2.3 Effect of Inlet Loading Rate on Removal Efficiency and Elimination Capacity

Two distinct zones were appeared (Fig.7.2) when RE and EC are plotted against Inlet loading rate in the biofilter for overall period of operation. During the whole experimental period total inlet loading rate of styrene was varied in the range of 17.5 to 1100.7 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. At the loading rate of 724 g $m^{-3}$ $h^{-1}$ the controlling mechanism is changing from mass-transfer to bioreaction which was evident by continuous decrease in RE with anincrease in loading rate. A nearly linear relationship between inlet loading and elimination capacity up to the loading rate 724 g $m^{-3}$ $h^{-1}$ was observed (Figure. 7.2). Beyond this value, the elimination capacity increased with comparatively slow rate and reached to its maximum value of 870 g $m^{-3}$ $h^{-1}$ at an inlet load of 990 g $m^{-3}$ $h^{-1}$.Similarbehaviour is also observed by Singh *et al*., (2010), Elmrini*et al*., (2004).

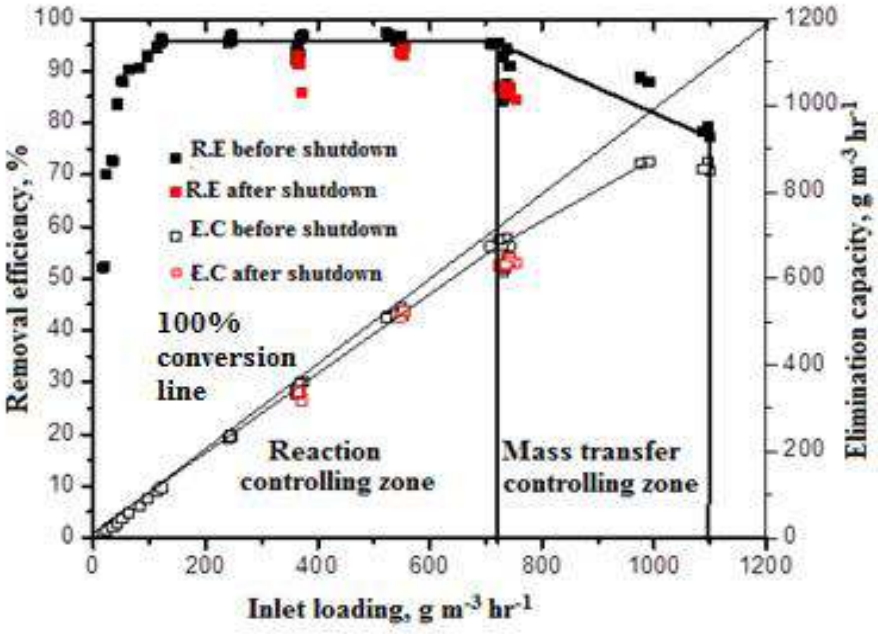


**Fig.7.2:**Variation of removal efficiency, elimination capacity with inlet load

### 7.3 Microscopic observation

The scanning electron micrograph (SEM) can provide information about the microbial community on the biofiltermedia. The biomass of individual particle can be mapped (Mathur*et al.*, 2007). Figure.7.3 shows SEM images of modified wood charcoal and compost composite beads before and after anacclimation period. It is clear from the figure that there is no growth before acclimation. After acclimation, it can be seen that rod-shape bacteria is formed on the surface of biofilter media containing a biofilm. Some fungi growth is also visible on the surface.

At last, summarily we can state that Continuous supply of nutrients in the biofilters for its successful operation is still a big problem from its commercial application point of view. In the present study, the results demonstrated successful biofiltration of styrene in the biofilter packed with compost and wood charcoal based modified biofilter media without asupply of nutrients for 131 days under high loading conditions. SEM results indicated effective growth of biofilm on the surface of biofilter media. Constant and more than 90% RE was obtained upto loading rate of 724 g $m^{-3}$ $h^{-1}$. The maximum elimination

capacity of 870 g $m^{-3}$ $h^{-1}$was obtained at the styrene loading of 990 g $m^{-3}$ $h^{-1}$. The pressure drop across the bed during thewhole operation was observed in the range of 5-7 mm of thewater column. During thewhole operation, thetemperature of inlet stream and bed temperature were found in the range of 26.5 - 31.2 and 28.9 - 36.3$^{o}$C 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%.

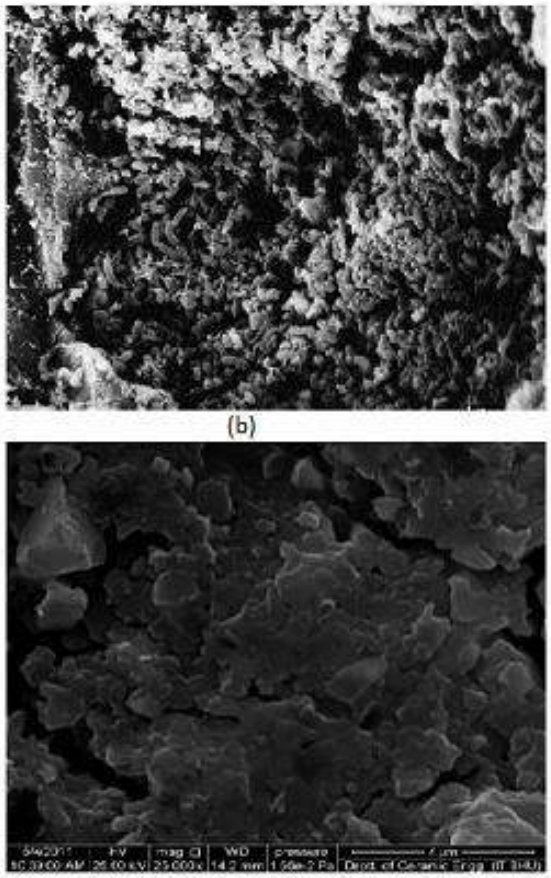


**Fig.7.3:**The surface morphology of biofilter media before (a) and after inoculation (b) using Scanning Electron Microscope (SEM).

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