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VOC REMOVAL THROUGH BIO FILTRATION USING LAB SCALE MODEL

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ABSTRACT

VOC – Volatile Organic Compound are compound with high vapor pressure and low solubility in water. In industry they are generated in waste gas stream from process with involvement of solvents like toluene, methanol, Iso Propyl Alcohol, Ethyl Acetate etc. Discharging VOC gas into the atmospheric air without any treatment then they are highly dangerous to human health as well as to ecological systems. Many physical and chemical Conventional treatment such as condensation, Scrubber, Incineration, adsorption, absorption are used to treat VOC from waste gas stream.Bbiological treatment for treating VOC is also proved an economic and effective option in industry at large scale level. Objective of the study to controlling VOC emitted from polymers manufacturing industry with the application of Lab-scale up flow bio filtration system. Basic Design & operational parameters such as empty bed residence time (EBRT) of 60-70 s, Media using wood chip (80%) and compost (20%) , Addition of nutrient, Mass loading Rate and removal efficiency (RE) has been studied for effective working. Mainly influencing parameters are pH, Moisture Content, Temperature, Nutrient requirement, EBRT rreviewed. The experiment was performed for three chemicals which are involved on VOC generation in polymer business that are Toluene, Methanol and Epichlorohydrin (ECH).

KEYWORDS: Volatile Organic Compounds, Bio filtration, Elimination Capacity, Empty Bed Residence Time, removal efficiency

I. INTRODUCTION

VOC are now in fall into major pollutant as it is found also in to air through indoor and outdoor source of emission. Most are carcinogenic and lead to photo chemical reactions. Main Source of the Emissions are large scale chemical processes in industry like paints, polymers, intermediates, varnishes and thinners, petroleum products etc. From transportation and biological processes also emit VOCs into air. These VOC gas is harmful to human and environment in many ways. Control on its emission and treatment of waste gas up to standard norms becomes a very necessary for all.

The organic hydrocarbon compound which are easily vaporized recognized as VOC. Technically such compounds are defined as organic compounds which has vapor pressure of 1% at sea level. These compounds may include several aromatic hydrocarbons and considered into the common category due to their similar physical behavior in the atmosphere. Due to its lower boiling point and high vapor pressure they easily vaporized and mixed with the atmospheric air directly.

Toxic volatile organic compounds (VOCs), such as benzene, toluene, Methanol, ethyl benzene, xylenes, and other solvents are air pollutants posing a threat to human health. They are directly associated with emission sources like transportation activity and industrial emission.

Based on nature, There are main three types of treatment techniques – chemically, biologically and physical treatment. Where waste gas flow rate is high and heavy concentration of VOC involved – physio-chemical treatment is suitable. Biological techniques are important where low flow and concentration is low up to 70 – 100 ppm. Main benefit of is Biological method can be operate at normal range of temp. Up to 40 ºC and at atmospheric pressure. Biological processes are very less expensive and simple in operation wise as well as ecologically clean as compared to physio chemical techniques. In this work, we focused on controlling Toluene, Methanol and ECH which is being emitted from polymer manufacturing industry.

II. METHODOLOGY

Basic bio logical process of degradation is shown in Fig. 1. Here Packing media Wood chips and Compost was used in proportion of 80 % & 20 % was used for the experiment.

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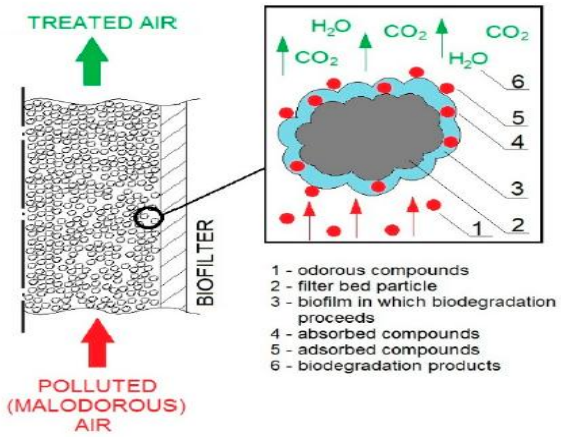

Figure:1 Basic Biological process

2.1 Packing Media Characteristics:

Compost:

Compost in fine shed form which has microorganisms in large diversity, moisture retention capacity is good, pH is 6.5 - 7.5and also contains organic form can be used in mixed proportion with wood chips. Many types of compost available in form of Sewage sludge, Cow dung manure, organic waste from sugar and rise mills, yard waste etc. In study compost from sewage plant is used for treatment.

Wood Chips/pellets:

Saw dust, wood ware or wood chips/pellets which are high in porosity and organic content can be used for mixing with compost. Commercially prepared wood chips or pellets of size 2-3 cm can be used.

Details of use packing media is given in Table : 1

Table 1. Details of used Compost and Wood Chips Medi

Property	Compost	Wood Chips
Moisture content , %	48	14
Porosity, %	72	--
C/N ratio	14.5	107
Microorganisms	Facultative bacteria	--

III. MODELING AND ANALYSIS

Experimental Model:

As shown in Figure 2 – Lab scale Bio filtration model was prepared for the experiment set up. In that model waste gas it means VOC gas will flow from bottom of the tower to top through the inserted packing media. Sample point is given at distance to measure the VOC value.

VOC was measured with the use of VOC gas analyzer of multi Rae Company. Media used in bio filtration is compost (20%) and Wood Chips (80%). Due to its capacity to water retention and organic content and porosity equal flow distribution throughout the bed with temperature around 40 ºC.

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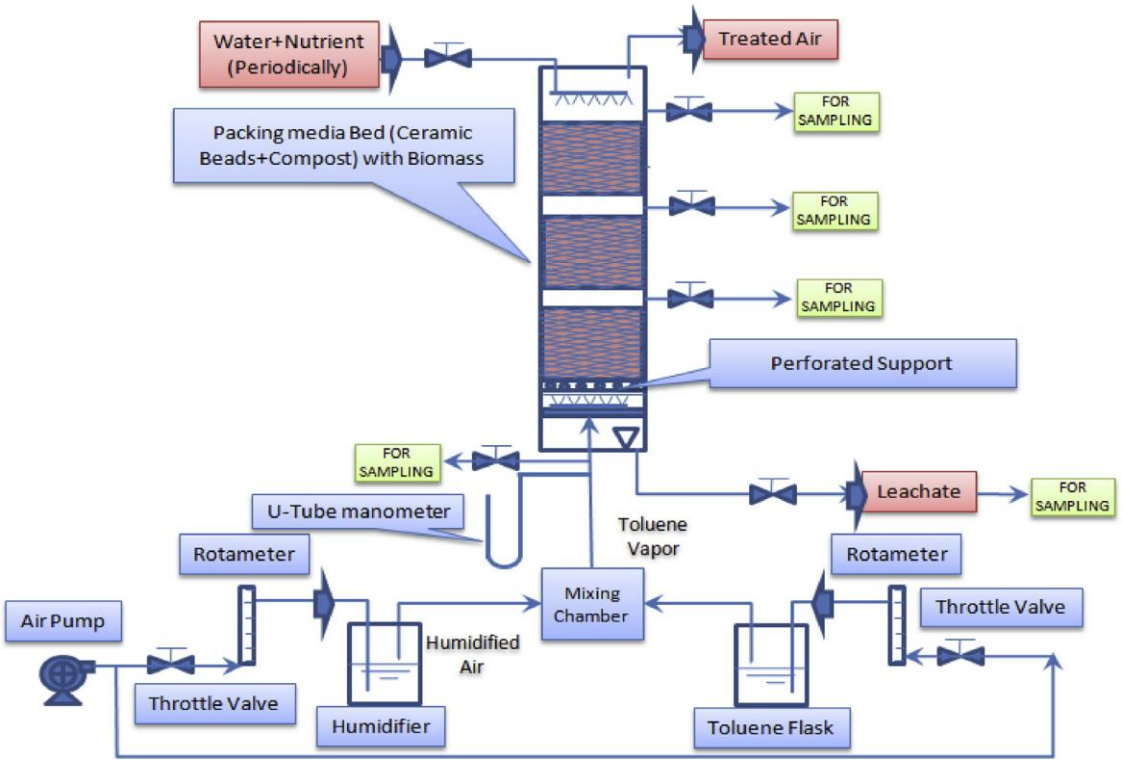

Figure: 2 Schematic diagram of experimental set

A SS Wire Mesh placed at the bottom accommodated the support for packing media for compost. Trial taken with packing media in proportion of 20 and 80 accordingly Compost and Wood Chips. Sampling port of 3 No. were placed with nob valve at equal intervals along the filter bed height of 15 cm. Liquid toluene was vaporized on Heating assembly followed by condenser effect to control temperature and humidified at constant air flow in a mixing chamber before entry to bio filter. Flow in Bio filtration tower was given in up flow mode in counter current direction. Experiment was tried on three types of VOC generating gas of polymer industry which are toluene, Methanol and ECH. Separate chemical was taken in heating assembly to generate VOC. It was mixed with then Air flow to adjust with the flow rate. Pressure drop monitoring gauge was installed I n inlet flow rate. To maintain moisture level in bio filter – water and nutrient spray from the top of the port was done regular interval and leach-ate generated from the tower will be collected at the bottom of the tower will be removed through bottom drain port.

Bio filter was operated in three operational phases and phase wise for removal of toluene, Methanol and ECH Separately. Bio filter was operated at the different flow and EBRT for the all three chemicals and moisture level maintained during experiment.

Detail specification of used bio filter is give in Table 2.

As VOC comes in contact with the bed material it gets degraded with the bacteria and stabilized into simple form.

Bacterial process in filter bed as under:

VOC gas + Media (Microorganisms) $\longrightarrow$ CO_2 (Gas) + H_2O + Bio mass

Table 2. Details of Equipment

Equipment specification	
Column Volume	8 Lit
Size of Bed	7.5 Lit
MOC of column	Poly Acrylic Glass
Sampling port distance, cm	15 (3 nos.)

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Support for media	40-mesh SS wire sieve
EBRT, s	70-90
Bed moisture content, %	50-70
Operating temperature, ºC	32 - 40
pH	6.8- 7.5

IV. RESULTS AND DISCUSSION

Performance of the Bio Filtration with Toluene - 30 %Compost and 70 % Wood Chips packing media used. Flow was maintained - 5 to 7 LPM.

EBRT - 75 Sec at Flow - 6 LPM

Table 3. Details of Toluene Trial

Run	Temperature	Inlet Conc ppm	Outlet Conc ppm	RE %	MC %	MLR g/m3hr	EC g/m3hr
1	40.3	85	65	23.53	54.9	68	16
2	38.2	90	70	22.22	56.4	72	16
3	36.1	97	50	48.45	56.8	77.6	37.6
4	37.5	86	45	47.67	57.5	68.8	32.8
5	38.4	89	41	53.93	58.6	71.2	38.4
6	37.5	88	34	61.36	58.3	70.4	43.2

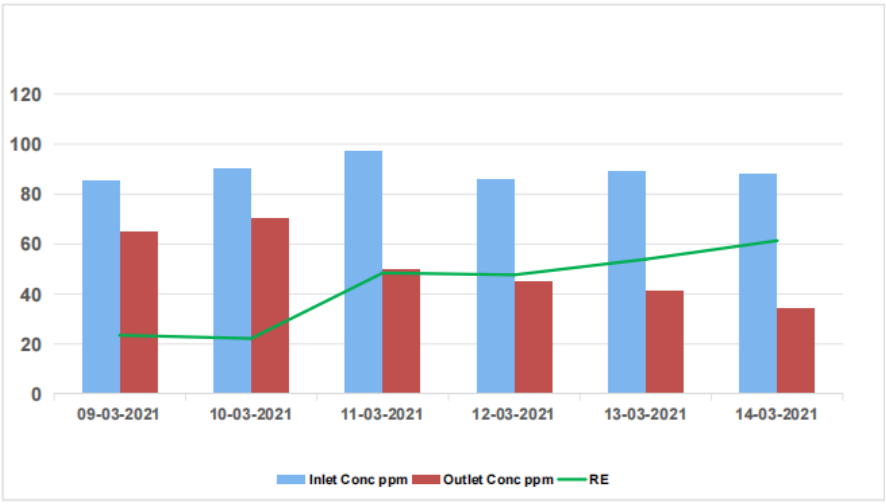

Figure:3 Variation of RE with Toluene Concentration

Performance of the Bio Filtration with ECH - 20 % Compost and 80 % Wood Chips packing media used. Flow was maintained - 5 to 7 LPM

EBRT - 81 Sec at Flow - 5.5LPM

Table 4. Details of ECH Trial

Run	Temperature	Inlet Conc ppm	Outlet Conc ppm	RE %	MLR g/m3hr	EC g/m3hr	MC %
1	40.3	95	58	38.95	70.37	27.41	51.2
2	41.2	98	51	47.96	72.59	34.81	58.6

3	39.6	92	42	54.35	68.15	37.04	57.1
4	36.8	89	34	61.80	65.93	40.74	54.2
5	39.5	95	28	70.53	70.37	49.63	52.6

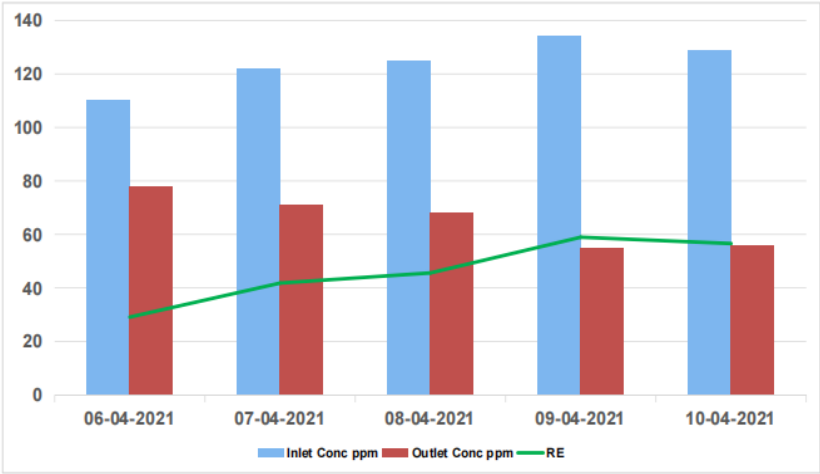

Figure:4 Variation of RE in ECH Concentration

Performance of the Bio Filtration with Methanol - 20 % Compost and 80 % Wood Chips packing media used. Flow was maintained - 5 to 7 LPM.

EBRT - 72 Sec at Flow - 6.2LPM

Table 5. Details of Methanol Trial

Run	Temperature	Inlet Conc ppm	Outlet Conc ppm	RE %	MLR g/m3hr	EC g/m3hr	MC %
1	41.5	110	78	29.09	90.41	26.30	48.5
2	40.5	122	71	41.80	100.27	41.92	53.21
3	39.5	125	68	45.60	102.74	46.85	51.2
4	38.5	134	55	58.96	110.14	64.93	53.5
5	39.5	129	51	60.47	106.03	64.11	58.5

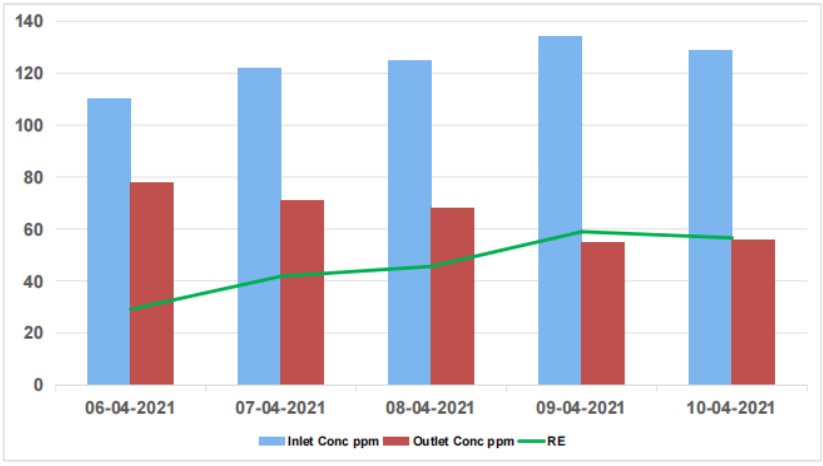

Figure:5 Variation of RE in Methanol Concentration

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Table 6. Summary of All Three Chemicals RE in %

Run	Toluene	ECH	Methanol
1	23.53	38.95	29.09
2	22.22	47.96	41.80
3	48.45	54.35	45.60
4	47.67	61.80	58.96
5	53.93	70.53	60.47

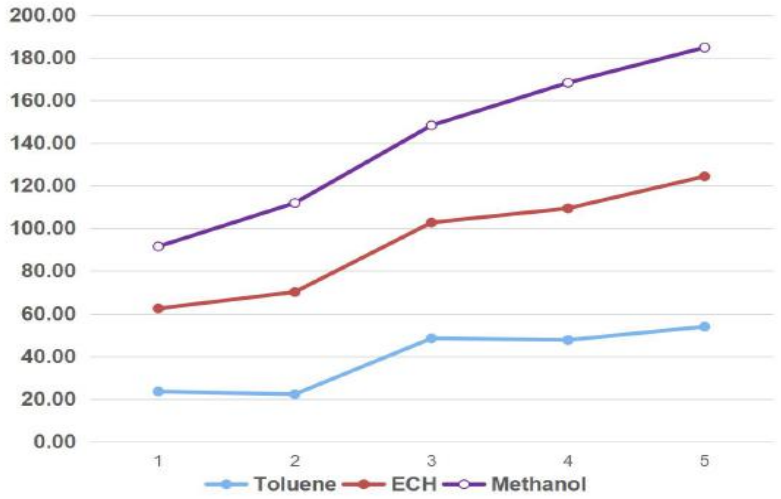

Figure:6 RE Variation in Toluene - ECH - Methanol

Experimental results are summarized in Table - 3-4-5 and represented in trend as shown in fig - 3-4-5.

Removal Efficiency of ECH chemical was high as compared to methanol and toluene. Though it would be high if we mix compound of VOC.

Experiment is performed with EBRT - 70 to 80 Sec. It is variable with the design parameter according to bed volume and design MLR - Mass loading Rate.

Performance of the Bio Filtration can be measured with basic calculation of Removal Efficiency, Elimination Capacity, EBRT and Mass Loading Rate.

These calculation was done as under:

Empty Bed Residence Time (EBRT):

EBRT is the time for that volume the gas retain in the filter bed during given fflow.

The actual gas residence time in the reactor can be calculated as the EBRT divide by the air-filled porosity available to gas flow, but such porosity is rarely known. EBRT is a simplified, relative measure of chemical residence time in a bio filter.

EBRT=(Vm/Q)/60

Where, Vm=biofilter packed bed volume (m3)

Q=Air flow Rate (m3/min)

EBRT=Empty Bed Residence Time(s).

Elimination Capacity (EC):

The elimination capacity is the amount of the pollutant or VOC removed by per volume of filter bed in unit time.

An overall elimination capacity is defined by Eq.

EC=Q (Ci-Ce)/V [g/m3/ h]

Where, Ci= Inlet concentration (ppm)

Ce= Outlet concentration (ppm)

Q=Airflow rate (m3/min)

V= Volume of bed (m3)

Removal Efficiency:

Removal efficiency is the percentage of removed pollutant fraction from the original inlet pollutant.

It is defined as

RE in % = (Ci-Ce)/Ci*100 %

Where, Where, Ci= Inlet concentration (ppm)

Ce= Outlet concentration (ppm)

Summary given Table 6 and In Figure. 6 Shows that RE of ECH was found high. Average RE for all three chemical was observed up to 60%.

However these data indicates that removal efficiency is not merely a function of loading rate, but also of residence time. For the same loading rate, reduced percentage removal occurred when the inlet concentration was lower and the residence time was decreased.

As bio degradation reaction is exothermic in nature will increase the temperature in filter bed. Temperature increase of 3 to 5 ˚C have been observed in many full scale bio filters. Further, Due to exothermic reaction media will get dry out in the center of the bed. Whereas the media near the reactor wall will remain with moisture content. Spraying of water from the top side of bio filtration tower maintain moisture content up to 50 - 60 % and temperature through the bio filtration tower.

V. CONCLUSION

Following conclusions can be drawn after Practical study and Literature Study:

Bio filtration is the more economical and easy to operate technology then physio-chemical process. As it also give effective result with the maintain of basic parameters like moisture, pH and temperature. In experiment Bio filtration was done for the three types of VOC gas - Toluene, ECH(Epichlorohydrin) and Methanol removal at polymer manufacturing industry by adopting media consisting of compost and wood pellets mixture.

In the Lab scale study, a flow rate maintained between 5 to 7 LPM and inlet concentration was maintained 100 – 130 ppm with EBRT 60 to 85 seconds has been investigated and a removal efficiency (RE) of 50 to 60 % for toluene, 50 to 70 % for ECH and 50 to 60 % for Methanol has been achieved with operating temperature ranging from 35 to 40 ˚C and Moisture content 50 to 60 % has been reported. Study also shows major operating problems such as increase in outlet air temperature by 3- 5 ˚C due to exothermic nature of bio degradation reaction as well as it also causes media dry-out problem. This requires continuous monitoring of outlet air temperature and relative humidity.

Study also reveal data that Inlet stream temperature to be controlled with pre condensing effect or Mixing with Air flow rate. In one run – Adding of pre assimilated Bio Culture in ECH gives better result as their oxidation capacity increased with active bio mass. Addition of nutrient can also impact the Bio Degradation process as like in Waste water treatment.

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