ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

BIOFILTER FOR THE PURIFICATION OF AIR CONTAMINATED WITH TRYETHYLAMINE (TEA)

B.Venu Gopal[1], A. Gangagni Rao[2], V. Sri Devi[*3],Y.Koteswar Rao[4], B.Siva babu[5]

1. M.Tech, School of Biotechnology, Department of Biotechnology, Institute of Science &Technology, Jawaharlal Nehru Technological University, Kakinada, East Godavari, Andhra Pradesh, India.

2. Senior principal scientist, Indian Institute of Chemical Technology, Tarnaka, Uppal road, Hyderabad, Andhra Pradesh, India.

3. Professor, Department of Chemical Engineering, Andhra University, Visakhapatnam-03, Andhra Pradesh, India.

4. M.Tech, School of Biotechnology, Department of Biotechnology, Institute of Science &Technology, Jawaharlal Nehru Technological University, Kakinada, East Godavari, Andhra Pradesh, India.

5. M.Tech, School of Biotechnology, Department of Chemical Engineering, Andhra University, Visakhapatnam-03, Andhra Pradesh, India.

Manuscript Info

Manuscript History:

Received: 10 December 2013
Final Accepted: 28 December 2013
Published Online: January 2014

Key words:
Triethylamine, biotrickling filters, bioscrubbers , biofilters,volatile organic compounds

Abstract

Bio-filtration is a method of pollution control in which pollutants are biologically degraded using microorganisms. Biofilters are being developed and effectively used for a wide variety of industries etc. Biofilters are cost-effective .Triethylamine(TEA) is a Volatile organic compound widely used as a catalyst for polymerization reactions and a solvent and corrosion inhibitor in industry and it is also used as an intermediate in the production of various chemicals, including pesticides. It is necessary to remove TEA from water and gas in the environment. In the present work, studies are being carried out on biofilter contaminated with TEA. The contaminated gas is passed through a packed bed where TEA compound is absorbed into the biofilm in which diffusion and aerobic biodegradation occur simultaneously in a complex set of physical, chemical and biological interactions. Therefore, selection of suitable microbial consortia and biofilter configuration is very important from commercial perspective. The present study is isolation and identification of TEA degrading microorganisms by selective media, biochemical tests, understand the microbial bio-degradation pathway of TEA, physical-chemical characteristics and adsorption studies of biofilter bed material, investigate the performance of biofiltration system in treating TEA under various conditions of inlet concentration, moisture content, pH etc are being carried out.

I. Introduction

The recent release on pollutant inventories published by various governments and environmental organizations demonstrate that emission of atmospheric pollutants in world has been increasing continuously. The industrial sectors such as chemical fertilizer, livestock, pharmaceutical, chemical, food processing, leather industry etc., are mainly responsible for these emissions. Amongst the industrial emissions, Volatile Inorganic Compounds, and Volatile Organic Compounds (VOC) are sources for health hazard gases and odor. Process industries like polymerization, hair curing plants, Tanneries, fish-meal manufacturing plants, wastewater treatment plants, landfills, livestock farms, hog manure etc., are generally located near urban areas and most prevalent health hazardous compounds are VOC is emitted from these operations. It has a bad odor and is considered a possible carcinogen; acute animal studies revealed that tri ethylamine caused dermal and ocular irritation, and severe toxicity and death following inhalation or oral exposure. Thus, the indiscriminate discharge of improperly treated contaminated emissions into an ecosystem will cause serious environmental pollution problems and severe adverse impacts on the ecology. However, adoption of stricter emission policies in recent years has greatly increased the inventory of compounds subject to regulation. As a consequence, biological treatment techniques for VOC and odor control have gained tremendous popularity in view of the several advantages they offer in comparison to traditional physical and chemical removal methods. Biological waste air treatment processes are not only cost effective but are also environment friendly .Furthermore, increasing costs of chemicals and disposal of hazardous wastes have provided further incentive for development and optimization of biological treatment methods. These bio treatment processes have found increasingly widespread application for the treatment of waste gas streams. However, increasingly with its more effective enforcement during the past few years, has forced technologists to examine hitherto neglected possibilities for efficient and economic waste gas treatment. This resulted in the development of new type of bioreactors such as biotrickling filters, bioscrubbers and biofilters. Biofilters are those reactors in which a humid polluted air stream is passed through a porous packed bed on which pollutant-degrading cultures are naturally immobilized. Biofilters excel in two main domains: the removal of volatile organic chemicals, from waste air. Under optimal conditions the pollutants are fully biodegraded and no wastewater production results.A bio filtration system consists mainly of a reactor packed with solid materials on which a bio film is formed, given the proper microbial population. When a contaminated air stream passes through the reactor, the pollutants are transferred to the biofilm where they are biodegraded to simple end products such as water and carbon dioxide. Consortiums of microbial populations are known to play an important role in this process. Studies on biofiltration over the last several decades have primarily been focused on odorous compounds such as hydrogen sulfide, ammonia, mercaptanes, etc. Biofiltration has emerged as one of the cost effective biological air pollution control technologies for treatment of volatile organic compounds(VOCs) emitted from chemical and process industries(Yoon and Park, 2002).Amines are widely used as catalysts in casting operations. Triethylamine (TEA) are the main gaseous catalysts for polymerization reactions comprising the majority of nitrogenous emissions (Borger et. al., 1997; Strikauska et. al., 1999; Busca&Pistarino, 2003). It has a very low odor threshold and exposure to it may cause adverse health effects. TEA causes environmental pollution problems and adverse effects on ecology. In addition, it can endanger human health. Animal experiments have revealed that TEA could cause irritation to the dermal, ocular and respiratory systems, such as asthma and visual disturbances (Belin et al., 1983; A kesson et al., 1985) and long-term exposure to TEA could result in abnormal embryos. TEA has been considered to be a possible carcinogen. Therefore, it is necessary to remove TEA from water and gas in the environment.

II. MATERIALS AND METHODS:

Biofilter Performance Criteria Parameters:

Empty Bed Residence Time (EBRT):

EBRT is the relative measure of gas residence time within the biofilter packed bed. 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 biofilter. Sufficient EBRT is necessary to allow transport and degradation of the pollutant to occur, which makes EBRT a critical design and operating parameter (swanson and Loehr, 1997).

EBRT=(Vm/Q)/60

Where, Vm=biofilter packed bed volume (m^3)

Q=Air flow Rate (m^3/min)

EBRT=Empty Bed Residence Time(s).

Surface Loading Rate (SLR):

The surface loading rate indicates the amount of air that is passed through the bioreactor per unit surface area per unit time.

SLR=Q/A [m^3/ m^2/ h]

Where, A= total surface of the packing or filter material in the bioreactor (m^2),

Q=Air Flow rate (m^3/hr).

Mass Loading Rate (MLR):

The mass loading rate gives the amount of pollutant which is introduced into the bioreactor per unit volume and per unit time.

MLR=Q*Ci/Vm[g/ m^3/ h]

Where, Q=Air flow rate(m^3/min)

Vm=Media volume (m^3)

Ci=Influent concentration (ppmv)

Elimination Capacity (EC):

The elimination capacity EC gives the amount of pollutant removed per volume bioreactor per unit time. An overall elimination capacity is defined by Eq.

EC=Q (Ci-Ce)/Vm [g/m^3/ h]

Where, Ci=Influent concentration (ppmv)

Ce=Effluent concentration (ppmv)

Q=Airflow rate (m^3/min)

Vm=biofilter packed bed volume (m^3)

Removal Efficiency (RE):

Removal efficiency is the fraction of the pollutant removed in the bioreactor expressed as a percentage. It is defined as

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

Where, Ci=Influent concentration (ppmv)

Ce=Effluent concentration (ppmv)

Source of Micro Organisms:

Triethylamine Oxidizing Bacterial strains (Aeromonassps.) is isolated from soil samples of leather industry effluents using MSM media.

Packing material:

The packing materials are two organic materials like wood chips and rice husk, one inorganic material like poly urethane foam (PUF). Wood chips average particle size is 10mm, and bulk density of 0.064gcm-^{3}. Rice husks average particle size is 10mm, and bulk density of 0.1087gcm-^{3}. PUF characteristics are bulk density of 0.0232gcm-3. Mixture of rice husk and wood chips were used as a organic packing material .bulk density of 0.0698gcm-^{3}. Mixture of Mixture of rice husk and PUF were used as a another packing material. Rice husk and PUF bulk density is 0.0835gm/

Specifications of biofilters

Biofilter-1

Diameter	0.05m
Area of column	0.1719m
Height of bed material	1.07m
Volume	2.09lit
Flow rate	2.4lit/min
EBRT=Vm/Q	47.6sec

Biofilter-2

Diameter	0.092m
Area of column	0.163m
Height of bed material	0.52m
Volume	3.4lit
Flow rate	4.2lit/min
EBRT=Vm/Q	52.24sec

Biofilter -3

Diameter	0.056m
Area of column	0.092m
Height of bed material	0.50m
Volume	1.2lit

Flow rate	1.3lit/min
EBRT=Vm/Q	57.6sec

Moisture content

An aqueous nutrient solution of 100ml was periodically distributed through a sprinkler system at the top of filter to provide the required nutrients for the biofilm and keep the media pH in a reasonable range, whereas same amount distilled water was added to biofilters to prevent the filter media from drying out. The nutrient solution for biofiltercontained(ing/L):K_2HPO_4(0.25),KH2PO4(0.1),ammoniumsulphate(0.2),magnesiumsulphate(0.02),agarpowder(1.6gm),TEA(50µl),H2O was added about 100ml and maintained moisture content in the range of 58 to 65% during biofilter operation.

Pressure drop

An air pump is required to pump a foul air stream through a biofilters. The electrical energy consumption of the pump is directly proportional to the pressure drop for the air stream flowing through the filter media. The pressure drop is generally affected by the void fraction, moisture content, and the structure of packing material, and increases with the superficial velocity of the flowing air across the cross-sectional area of the media. Additionally, the pressure increases as the packing media age or degrade.

pH

The pH increased gradually during the biofilter operation due to the accumulation of tryetylamine. Initially pH in biofilter (l) was 6.5 and the end of the operation it was increased to 7.0.These changes in pH affected the RE of the biofilter whereas for the biofilter II, initial pH of the biofilter was 7.1 and it raise to 7.2 only even after the operation of the filter for 45 daysThis may be due to biodegradation of TEA because of oxidation of tryethylamine with pure cultures of bacteria in the filter. and there was increase in the pH gradually along with the increase in the inlet concentration indicating that there is less efficiency of degradation after 200ppm.

Microbial count

To observe the growth of bacteria in biofilter system cell numbers were measured at the start and end of the experiment. About 2 gm of filter material was collected from biofilters and mixed in 100 ml of sterilized water in a flask. Flasks were and kept in the shake flask for 3 hours (shake flask model).Then 1ml of this sample was transferred to 9ml-distilled water and serial dilutions up to 10 dilutions. From each dilution 1ml of sample was added to nutrient agar Petriplates and kept for incubation at a temperature of 37 ^{o}C for two days. Colonies of growth from plates were counted and represented in CFU with respective dilutions.

Acclimation time

One of the major parameter of the study is to determine the time that bacteria need to oxidate to inlet TEA concentration. In this experiment of 40 days, the removal efficiency was low in the first few days during which bacteria were acclimated to TEA over approximately 7 days. After that, removal efficiency increased by up to 99.9% to 100% and the system became stable. At the beginning of the operation, the inlet concentration was 100 ppm, and then it increased gradually to about 200 ppm. During the first few days, the removal efficiency was low but after the acclimation period, the removal efficiency increased rapidly. Also, the maximum TEA removal efficiency was measured at above 99.9%. When the influent TEA concentration was between 100 to -200 ppm, the effluent TEA concentration was found to be less than 1 ppm in biofilter .

III. RESULTS AND DISSCUSIONS

Table:1 Performance of the biofilter-2

S.NO	Ci (ppm)	Co (ppm)	R.E (%)	E.C ($g/m^3/hr$)	M.C (%)	FLOW RATE(m^3/hr)	pH	EBRT (sec)	S.V Perhour	S.L.R $m^3/m^2/sec$	C.F.U	M.L.R
1	3.35	1.56	53.6	0.518	56.65	4.2lit/min (or)	6	47.6	74.11	0.0106	$5.560*10^9$	0.496

2	7.1	2.5	64.7	1.408	56.65	$0.004m^3/min$ (or) $0.00007m^3/sec$ (or) $0.25m^3/hr$	6.1	47.6	74.11	0.0106		1.124
3	8.91	3.9	56.2	1.549	56.65		6.2	47.6	74.11	0.0106	$3.910*10^{11}$	1.408
4	14.13	6.1	56.82	2.483	60.65		6.3	47.6	74.11	0.0106		2.233
5	20.72	8.8	57.48	3.691	60.65		6.4	47.6	74.11	0.0106		3.276
6	40.5	16.2	60.11	7.478	60.65		6.5	47.6	74.11	0.0106		6.411
7	40.86	5.31	87.12	10.924	57.65		6.5	47.6	74.11	0.0106		6.468
8	49.65	6.65	86.61	13.259	57.65		6.5	47.6	74.11	0.0106		7.861
9	52.65	8.15	84.52	13.734	58.65		7	47.6	74.11	0.0106		8.335
10	50.41	10.6	78.59	12.303	58.65		7	47.6	74.11	0.0106		7.981
11	50.36	8.15	83.81	13.029	58.65		7	47.6	74.11	0.0106		7.972
12	55.48	9.15	83.51	14.304	59.07		7.5	47.6	74.11	0.0106	$4.510*10^9$	8.781
13	56.18	9.16	83.69	14.519	59.07		7.7	47.6	74.11	0.0106		8.892
14	56.7	8.13	85.48	14.979	59.07		7.9	47.6	74.11	0.0106	$2.560*10^{10}$	8.976
15	57	8.25	85.52	14.994	59.07		7.9	47.6	74.11	0.0106		9.022
16	58.5	9.09	84.46	15.238	58.07		7.9	47.6	74.11	0.0106		9.262
17	64.56	9.32	85.56	17.024	58.07		8	47.6	74.11	0.0106		10.221
18	70.36	9.32	86.75	18.803	58.07		8	47.6	74.11	0.0106		11.137
19	68.56	8.25	87.96	18.551	58.07		8	47.6	74.11	0.0106		10.855
20	63.81	8.5	86.67	17.017	57.07		8	47.6	74.11	0.0106		10.102
21	76.05	9.2	87.99	20.552	57.07		7.1	47.6	74.11	0.0106		12.038
22	63.72	6.3	90.11	17.654	57.07		7.1	47.6	74.11	0.0106		10.087
23	85.5	6.84	92.12	24.177	59.10		7.1	47.6	74.11	0.0106		13.535
24	88.36	7.2	91.85	24.948	59.10		7.4	47.6	74.11	0.0106		13.989
25	93.6	7.6	91.88	26.415	59.10		7.4	47.6	74.11	0.0106		14.818
26	113.4	8.55	92.46	32.256	59.10		7.4	47.6	74.11	0.0106		17.953
27	106.5	9.65	91.22	29.765	60.10		7.4	47.6	74.11	0.0106		16.861

28	118.4	12.4	89.5	31.944	60.10
29	126.7	9.63	92.39	36.021	60.09

6.85	47.6	74.11	0.0106		18.747
6.85	47.6	74.11	0.0106		20.045

Figure :1 Variation of R.E with inlet TEA concentration

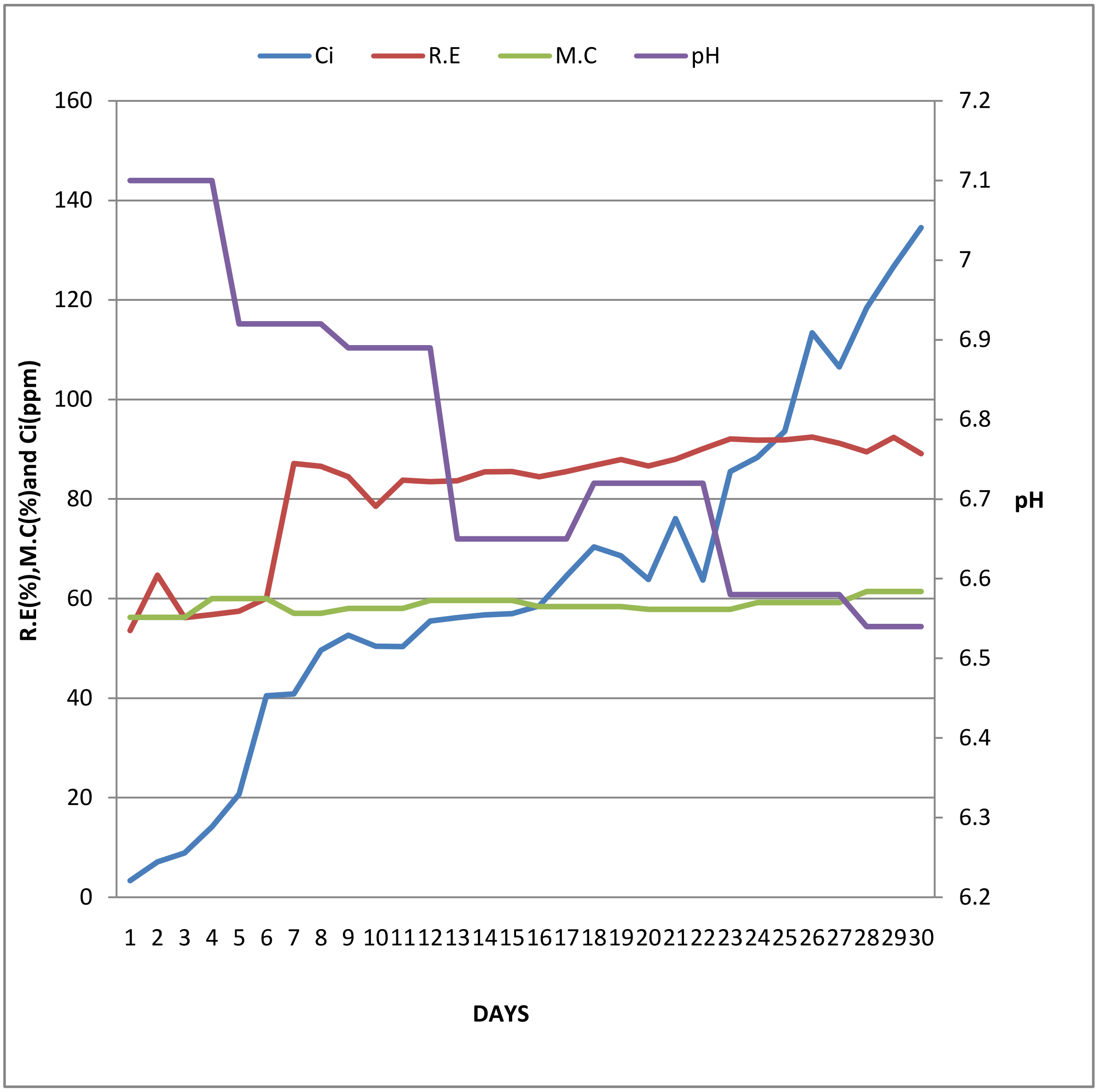

Figure: 2 Variation of pH with R.E, M.C and Ci

IV. Conclusion

Isolation of TEA oxidating bacterial strains from soil sample of leather industry effluent shows the higher TEA assimilation ability and effective growth rate at the concentration of 500 ppm in nitrogen limited media with the pH range of 7.5 to 8.5; consequently reduce the addition of buffering agents for pH maintenance in the biofilter. In the present work, biofiltration studies for TEA removal used wood chips as filter material was inoculated with co culture of isolated TEA assimilating bacteriaspecies and various process parameters which are important for biofilter performance evaluation have been studied. The results obtained shows that, no oxidation period was needed to reach such a high efficiency in the removal of the tryethylamine because of specific bacterium isolation instead of sludge inoculation, indicating the ability of this bacterium to remove NH_3 which occurred immediately after its inoculation to the filter media. The operational parameters of the biofiltration system were determined at various air flow rates (0.252 $m^3\ h^{-1}$,0.144 $m^3\ h^{-1}$,0.078 $m^3\ h^{-1}$) and NH_3 concentrations (100–200 ppm). The results shows that biofilter-II which was operated by inoculating with co cultures of TEA assimilating bacteria is found to superior than biofilter-I in terms of stable and higher RE, stable pH and higher EC which are critical parameters for biofilter operation and performance evaluation. No remarkable decline of pH during the 40 days operation, mainly because of the TEA removal in second biofilter.

References:

Borger T, Salden A, Eigenberger G (1997). A combined vacuum and temperature swingadsorption process for the recovery of amine from foundry air. ChemEng Processing,36: 231-38

Busca G, Pistarino C (2003). Abatement of ammonia and amines from waste gases: asummary. J Loss Prevention in the Process Industries, 16: 157-66.

Delhomenie, M.C., Bibeau, L., Bredin, N., Roy, S., Brousseau, S., Kugelmass, J.L.,Brzezinski, R., Heitz, M., 2002.Biofiltration of air contaminated with toluene ona compost-based bed. Advances in Environmental Research 6, 239–244.

Mohseni, M., Allen, D.G., 2000.Biofiltration of mixtures of hydrophilic and hydrophobicvolatile organic compounds. Chemical Engineering Science 55,1545–1558.

Pedersen, A.R., Arvin, E., 1995. Removal of toluene in waste gases using a biologicaltrickling filter. Biodegradation 6, 109–118.

Pedersen, A.R., Moller, S., Molin, S., Arvin, E., 1997. Activity of toluene-degradingPseudomonas putida in the early growth phase of a biofilm for waste gastreatment.Biotechnology and Bioengineering 54, 131–142.

Swanson, W.J., Loehr, R.C., 1997. Biofiltration: fundamentals, design and operationprinciples, and applications. Journal of Environmental Engineering 123, 538–546.

Strikauska S, Zarina D, Berzins A, Viesturs U (1999). Biodegradation of ammonia by twostage biofiltration system.Environ Eng policy, 1: 175-82

Yoon IK, Park CH (2002). Effects of gas flow rate, inlet concentration and temperature onbiofiltration of volatile organic compounds in a peat packed biofilter. J BiosciBioeng,93: 165-11.