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Control of Odour, Volatile Organic Compounds (VOCs) & Toxic Gases through Biofiltration - An Overview

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Abstract- ***Direct emission of biodegradable volatile organic compounds (VOCs), odorous compounds and toxic gases from the wide range of industries and public sector sources into the environment is one of the serious issues as it leads to adverse environmental impact and public health risk. It makes the control of above pollutants necessary. This paper presents an overview on one of the Biological techniques i.e. Biofiltration for the treatment of off-gases which uses microorganism to break the biodegradable pollutants, the sources of such pollutants and extent of pollutants that a biofilter can remove. This paper also gives a perspective of various factors governing the performance of biofilters, and efficiency changes with a change in the type of filter media (peat, compost, chaff, perlite, oyster shells & wood chip), its effectiveness in various industries along with its principle and basic design.From review it is found that the removal efficiency ranges from 30% to 100% & its relative cost is very low compared to other treatment methods that make it cost effective. The main purpose of using biofilter for study is to encourage its implementation at appropriate locations.***

Keywords: Biofiltration, biofilter, microorganism, odour, VOCs

INTRODUCTION

Most of the industrial and domestic activities generate gaseous emission that leads to odour nuisance, adverse impact to human health and environment. Odour, Volatile Organic Compounds (VOCs), particulate matter and toxic gases are few contaminants among them. As per the definition of EPA, "VOC is an organic compound that participates in atmospheric photochemical reactions except those having negligible photochemical reactivity". VOCs includes degreasers, solvent thinners,lubricants, cleaners and liquid fuels like methane, perfluorocarbons and chlorohydrocarbons. VOCs are commonly emitted from petroleum and Chemical Industries(Khan and Ghoshal 2000). Landfills, food, textile plants, pulp and paper industries, composting plants, wastewater treatment plants and other sources like animal husbandry are the potential source of the offensive odour(Dincer, Odabasi, and Muezzinoglu 2006; Melse and Hol 2017; Saral and Demir 2009; Shon *et al.* 2005; Ying *et al*. 2012). The odour originates due to biological and chemical processes from landfill sites during waste decomposition. The present rate of industrial development and population growth needs VOCs &odour control system to provide contaminant-free breathing air. Biological waste air treatment is best for this as it is cost effective as well as environment friendly in comparison with conventional techniques such as adsorption or incineration (Delhom 2005). The biological treatment utilizes microbes to treat contaminant emitted in the air. Contaminants act as the energy source for microbial growth. The principle of waste air treatment is very simple contaminants are sorbed from a gas to aqueous phase where the microorganism attacksand finally carbon dioxide, water vapour, and organic biomass are obtained as end product through the oxidative and reductive reaction(Devinny, Deshusses, and Webster 1999).

Basic design

Biofilter consists of one or more beds of biologically active material, usually mixtures of peat, compost or soil(Leson, Winer, and Leson 2012). The support to microbial growth makes biofilter bed as a heart of the biofiltration process, for ideal biofilter bed:(a) specific surface area should be high for the development of a microbial biofilm and gas-biofilm mass transfer, (b) porosity should be high to facilitate homogeneous distribution of gases, (c) to avoid bed drying the water retention capacity should be good, (d) intrinsic nutrients must be available, and (e) presence of a dense and diverse indigenous microflora(Bohn 1992). Efficiency for different filter media for removal of some commonly found odorous compound and VOCsis given in table 1.

Sometimes coarse fraction is provided below filter bed that acts as a supporting material and the supporting material may consistof inert material like lava particles or polystyrene, or partially active natural material like wood chips, wood bark, and heather. It helps in preventing high pressure drops in filters.(Hesselink 1993).Commonly, filter beds are of 1 meter height. A biofilter comprises of the following five parts: a waste air distribution system, a ventilator, a humidifying section, one or more layers of filter material, an additional water supply unit for industrial scale only(M. Deshusses and Digestion 2014). It may be an open bed or close bed type. Fig 1. & fig 2. Shows the open bed and close bed filters.

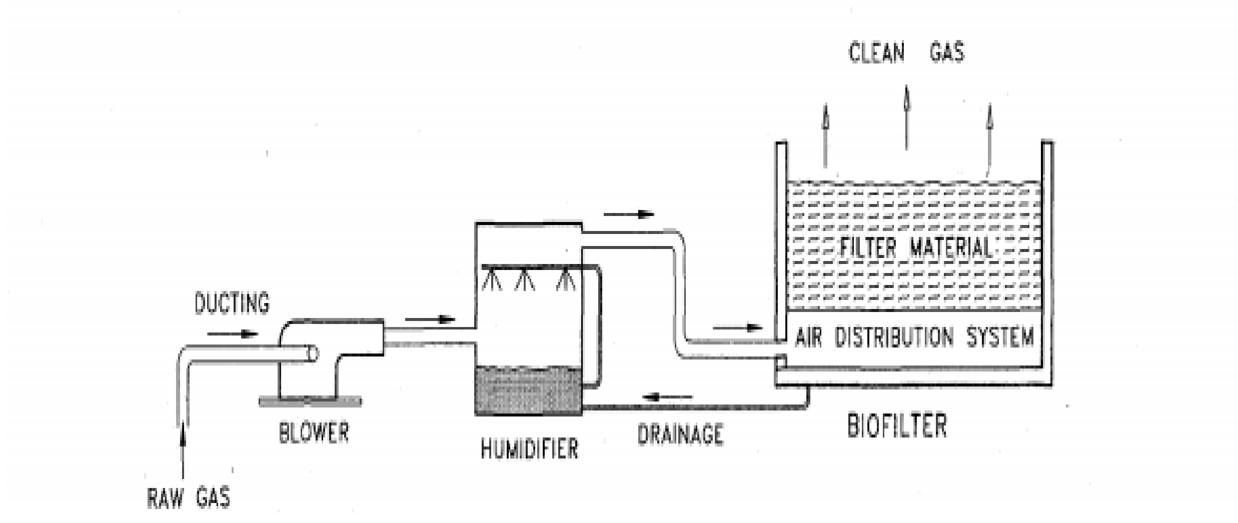

Figure 1. Open single-bed biofilter system(Leson, Winer, and Leson 2012)

Operation and mechanism

Physicochemical and Biological phenomena occur simultaneously during the pollutants degradation in the biofilm of a biofiltration,Biotransformation occurs along with adsorption, absorption and diffusion to remove contaminants from the gaseous stream(M. A. Deshusses n.d.). Contaminated gas emitted from the source is directed to filter, by providing sufficient residence time the air contaminants get diffused into a wet, Biologically active layer (biofilm) around the filter particles(Leson, Winer, and Leson 2012). In the presence of microorganism mainly bacteria in biofilm will Aerobically degrade the targeted pollutant(s) and the end products after complete biodegradation of air contaminants are CO_2, water, and microbial biomass fig.1 (Devinny, Deshusses, and Webster 1999). The operating conditions should be according to typical values of the parameter in table 1.

$$Organic\ Pollutants + O_2 \xrightarrow{Microorganism} CO_2 + H_2O + Biomass$$

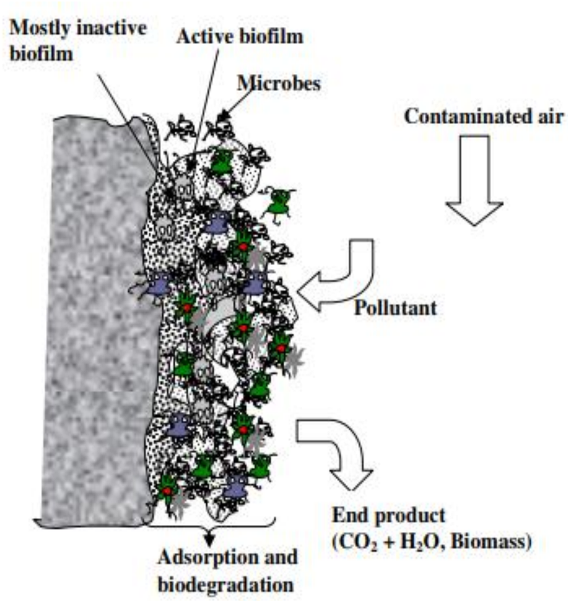

Figure 2. Phenomena associated withbiofilters operation(Kumar, Kumar, and Chandrajit 2011)

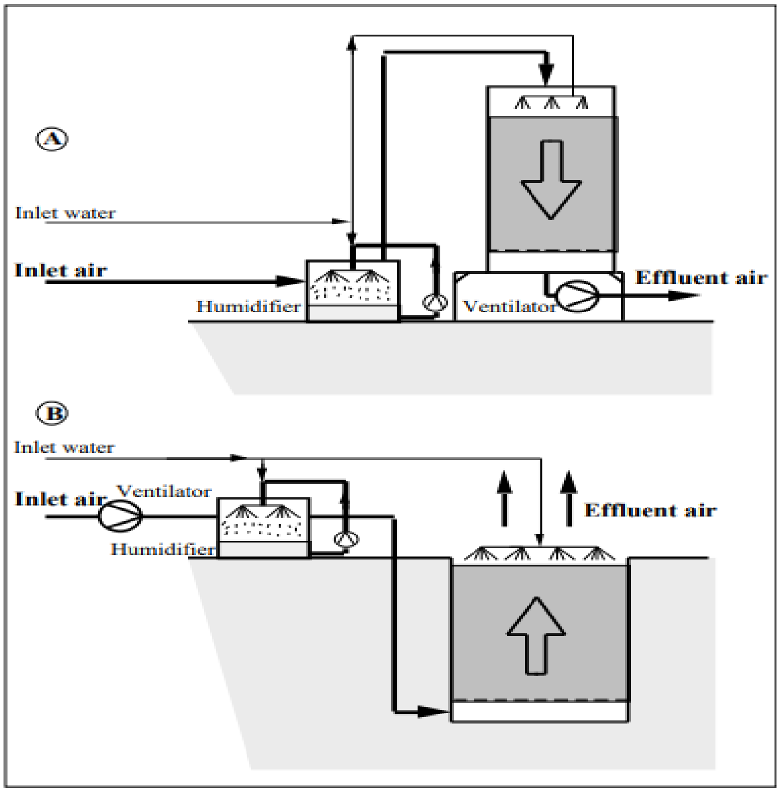

Figure 3. A) a closed biofilter and B) an open air biofilter. (M. Deshusses and Digestion 2014)

Table 1: Typical Biofilter Operating Conditions for Waste Air Treatment(Devinny, Deshusses, and Webster 1999)

S.NO.	Parameter	Typical Value
1	Biofilter layer height	1-1.5 m
2	Biofilter area	1-3000 m^2
3	Waste air flow	50-300,000 m^3h^{-1}
4	Biofilter surface loading	5-500 $m^3m^{-2}h^{-1}$
5	Biofilter volumetric loading	5-500 $m^3m^{-3}h^{-1}$
6	Bed void volume	50%
7	Mean effective gas residence time	15-60s
8	Pressure drop per m of bed height	0.2-1 cm water gauge (max. 10 cm)
9	Inlet pollutant and/or odour concentration	0.01-5 gm^{-3},500-50,000 OU m^{-3}
10	Operating temperature	15-30 °C
11	Relative humidity of inlet air	>98 %
12	Supporting material water content	60% by mass
13	pH	6-8
14	Removal efficiency	60-100%

Performance of biofilter

Performance highly depends upon nutrients, pH, oxygen level, moisture content and filter media. Biofilter degrading capacity gets improved by the addition of activated carbon, eliminate hydrophobic compounds, and provide better control over loading variations(Leson, Winer, and Leson 2012).

Nutrients

The pollutant entered into bed are the major source nutrient as carbon, hydrogen & oxygen are available in air and sometimes in VOCs helps in microbial activity. Other macronutrient like N,P,K & S and micronutrient likemetals& vitamins requirementis completed partially by filtering material used. Compost as filtering media is best as it contains various nutrients as well as it is the waste product.

Nutrients are supplied either in the solid form which is directly inserted into the filter bed or as aqueous solutions for microbial growth, which is the most frequently used method(Gribbins *et al*. 2011). The most widely recognized nutrient solutions utilized in biofiltration are KH_2PO_4, $Na_XH_{(3X)}PO_4$, KNO_3, $(NH_4)_2SO4$, NH_4Cl, NH_4HCO_3, $CaCl_2$, $MgSO_4$, $MnSO_4$, $FeSO_4$, Na_2MoO_4, and vitamins (B1, etc.)

pH

In the biological process, pH significantly influencesbiofiltration efficiency. Deviation from optimum pH range severely affects microbial activity. The majority of the microorganisms in biofiltration are neutrophilic i.e. their optimum pH is 7(Lu, Lin, and Chu 2002). Most extreme degradation of Benzene, Toluene, Ethylbenzene, Xylenes(BTEX) between pH values of 7.5 and 8.0 is observed(Taylor *et al.* n.d.). pH 7.0 is ideal for BTEX decomposition.(Veiga *et al.* 1999)

Moisture Content

Presence of proper moisture in BFs is helpful for microorganisms to carry their normal metabolic activity. Too high or too low moisture content will cause the significant reduction on biodegradation rate, excess water results in the development of anaerobic conditions.

Optimal moisture content varies with different filtering material as with variation in filtering materials porosity, surface area and other factor changes. Supplement moisture supply should be for packing materials, its drying results in non-uniform distribution of gasesand diminutionin microbial activity(Shareefdeen, Herner, and Singh 2005).

Oxygen level

Oxygen level plays important role in a performance of biofiltration. Various experiment suggests different things, oxygen rich air improves the biofiltration performance and oxygen was found as a limiting factor(Kumar, Kumar, and Chandrajit 2011). In another experiment, where there is a simultaneous removal of a mixture of methyl isobutyl ketone (MIBK) and methyl ethyl ketone (MEK), with the increase in oxygen level in air significant improvement is not found(M. A. Deshusses, Hamer, and Dunn 1996).As a result, oxygen's role was found case specific in biofiltration performance. But, inorder to avoid the anaerobic condition, proper oxygen level should be maintained. Presence of even micro-anaerobic conditions lead to the formation of odorous compounds and this deviates from the ultimate objective of removing odorants and VOCs.

TABLE 2: Removal efficiency of some commonly found odorous compounds and VOCs with different filtering media.

s.no.	Media	Pollutant	Removalefficiency %	Reference
1	Peat	Ethanol	30	(Ex and Devinny 1997)
2	Conditioned peat	Xylene isomers	52	(Bioülter *et al.* 1998)
3	50% compost, 50% perlite	Hexane	>95	(Morgenroth *et al*. 2012)
4	50% compost, 50% chaff	Triethylamine	100	(Tang *et al*. 2012)
5	50% compost, 50% perlite, oyster shells	Methylene dichloride	>98	(Ergas *et al.* 1994)
6	Wood chip	NH_3	42-62	(Melse and Hol 2017)
7	Wood chip	Odour compound	42-62	(Melse and Hol 2017)

Cost effectiveness

Waste air treatment is the costly process. It can be single or combination of processes like thermal incineration, catalytic incineration, adsorption, absorption in water, chemical oxidation, bioscrubber, biofilter.The effectiveness of biofilter is clear by comparison of relative cost for different treatment for the gas flow of 10,000 m^3h^{-1} and VOC of 100-2000 mg m^{-3}as stated in table3

TABLE 3: Relative cost comparison of different types of treatment(Suresh T. Nesaratnam n.d.)

S.NO.	Type of Treatment	Relative Cost
1	Thermal Incineration	7-9
2	Catalytic Incineration	6-8
3	Adsorption	14-18
4	Biofilter	0.5-3

Applications

Effectiveness of biotechnology makes its applications in various industries and it also promotes the use of biofiltration, contaminants removal efficiency in different industries according to multiple studies are in table 4.

Table 4: Application of biotechnology in different industries(Suresh T. Nesaratnam n.d.)

S.NO.	Industries	Application	Efficiency(%)
1	Gelatin production	Odour removal	70-93
2	Cocoa and chocolate processing	Odour removal	99
3	Waste water treatment	Odour& H_2S removal	90-95
4	Flavor and fragrance	Odour& H_2S removal	98
5	Food processing	Odour removal	93
6	Ceramics processing	Ethanol removal	98
7	Metal foundry	Benzene removal	80

CONCLUSION

The review provides an outline of biofilter along with performance governing parameters. It confirms the extent of effectiveness of biotechnology for different gaseous pollutants as VOCs, odour& toxic gases like H_2S treatment. It also provides the information about the change in efficiency with the change in filter media used in biofiltration.
There is need to work on the aspect how to make this process applicable for highly polluted air stream or stream containing multiple pollutants, determining the parameter apart from above four which will affect the working of biofilters. Its cost analysis at different work scale can also be the area of work.

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