TREATMENT OF PALM OIL MILL EFFLUENT ODOUR USING BIOFILTER FROM COMPOST AND WOOD CHIPS MEDIA

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SCHOOL OF CIVIL ENGINEERING
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By

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I hereby declare that all corrections and comments made by the supervisor(s) and examiner have been taken into consideration and rectified accordingly.

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ABSTRAK

Bio-penapis merupakan satu sistem yang mengandungi bahan organik yang dihuni oleh mikroorganisma, yang akan mengurangkan konsentrasi bau yang mengalir keluar daripada sistem tersebut. Kajian ini dijalankan untuk mendapatkan bahan media yang berkesan atau bahan media campuran dengan kadar pecahan yang patut dan operasi bagi sistem bio-penapis. Serpihan kayu dan kompos yang digunakan pada bio-penapis sebagai bahan media turut di ujikaji kerana ia merupakan salah satu parameter untuk kebolehkesanan sistem ini. Air sisa keluaran dari memprosesan kelapa sawit turut diuji untuk mengenalpasti kadar pengurangan bau pada sistem bio-penapis yang berbeza penggunaan media dengan kadar pecahan yang berbeza. Pengumpulan data dapat dikumpul dari dua bio-penapis yang berbentuk penggunaan makmal dan ia terletak di makmal alam sekitar. Sampel udara bau busuk yang masuk dan keluar dari bio-penapis dikumpulkan untuk menjalankan ujikaji . Manakala, pH bagi bahan media dan tekanan udara sampel gas bagi masuk dan keluar dari bio-penapsi akan diambil terus pada bio-penapis di makmal. United Oil Palm Industries Sdn.Bhd telah memberi kebenaran untuk mengambil air sisa kelapa sawit bagi penggunaan ujikaji. Selain itu, pelbagai ujikaji turut dijalankan bagi sampel bahan media iaitu ujian ciri –ciri bahan media. Kadar pengurangan bau untuk kesemua bio-penapis yang diterima adalah berbeza. Hal ini, disebabkan berlaku diatas pelbagai parameter bagi bio-penapis. Masa tahanan lapisan media adalah sama iaitu 60 saat. Seterusnya, pH bagi kesemua bio-penapis media adalah nilai optimum dimana melalui ujikaji yang dijalankan mendapati nilainya terdekat dengan nutral pH iaitu 6.5. Kompos kelapa sawit menunjukan nilai ciri – ciri yang baik daripada serpihan kayu. Pengurangan udara bagi kompos adalah 96%. Melalui kajian ini, jurutera - jurutera dapat mengenalpasti parameter penting bio-penapis di samping memperkenalkan bahan baru untuk penapis.

ABSTRACT

A biofilter is one of the system which are consists of micro-organisms populated container of organic material, through which will reduce the odour concentration flowing out from the system. The study was conducted to determine the suitable media or ratio of mixed media and operation condition for biofilter. The characteristic of wood chips and compost used for packing material in biofilter was conducted as it is one of the prime parameters for biofilter performance. The Palm Oil Mill effluent was tested to identify the odour removal efficiencies at varying biofilter operational conditions. The data collection is obtained from two biofilter which is in form of lab scale and it located at the laboratory. The sample gas of inlet and outlet from biofilter are collected for testing while data such as pH of filter media and pressure flow rate of gas sample inlet and outlet is taken directly at the biofilter at laboratory. United Oil Palm Industries Sdn.Bhd have been given permission to take palm oil effluent for research. Other than that, various test for the biofilter media samples was also conducted. Some of tests are conducted for the important parameter of biofilter performance which is characteristic test for media. The odour removal efficiency of all biofilters are obtained in different removal capacity. This conditions is occurred because can be affected by many parameters of biofilter performance. The Empty Bed Retention Time for all biofilter is same which 60s. Next, the pH for both biofilter media is optimum pH which through test pH value is reduce near to neutral pH is 6.5. The palm oil compost show better result in many physical parameters compared to wood chips. The odour removal efficiency results for compost is 96%. This research will help the engineers to determine the important parameters to consider for design and to open up new opportunity to introduce new type of filter media.

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LIST OF ABBREVIATIONS

FE	Finite Element
RE	Removal Efficiency
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CPO	Crude Palm Oil
EBRT	Empty Bed Retention Time
FFB	Fresh Fruit Branch
MPOC	Malaysia Palm Oil Council
POME	Palm Oil Mill Effluent
SEM	Scanning Electron Microscope
VOC	Volatile Organic Compounds

NOMENCLATURES

M_D	Mass Of Dried Soil
M_W	Mass Of Water Removed By Drying
Pa	Pascal
V_V	Volume Voids
$\mathrm{V_T}$	Volume Totals
W	Moisture Content
CH_4	Methane
H_2S	Hydrogen Sulfide
$\mathrm{NH_3}$	Ammonia

CHAPTER 1

INTRODUCTION

1.1 Background

Odour is sensation of a substance that will activate the sense of the smell. Odour one of the subjective in characteristic. Normally the odours are impossible to be precisely interpreted by different individuals. Different individual may have their own responses to the odour which they could depend on the variation of concentration, duration of exposure and their function. Other than that, odour also one of the environmental component which can be contribute to its changes. The environmental changes could impact the health and human well-being. Odour can be produce from many types such as industrial, commercial, agricultural, animal production and etc.

As know that Malaysia is the biggest producer of palm oil. According to current data collection for 39% of the world palm oil production and 44 % will be of world exports (MPOC., 2014). Other than that, the oil and fats produce in country, Malaysia results for 12% and 27% for the total of the production and also one of the exports of oils and fats (MPOC., 2014). Throughout the increase in palm oil production, this also will result to the increases in the waste products from palm oil industry.

From palm oil industry, there were about two type of waste are produced, which is solid and in liquid form. If liquid form are known as palm oil mill effluent (POME). POME are normally look like thick brownish of liquid waste, high in colloidal suspension and also have unpleasant odour (Ahmad et al., 2009). The higher portion of the raw POME was water with 95-96% and made up with 0.6-0.7% oil and 4-5% total solids (Ma, 2000; Ahmad et al., 2003)

There were many technologies and developed have been taken for the odour management that produce from POME at overseas but at Malaysia there still improving the system of odour treatment to reduce the odour. Such as biological treatment, chemical treatment and biofiltration which this technologies. The biological treatment method is one of the ways to treating the effluent water. The biofiltration process is managed using the biofilter media system for treating odourous air stream. As odourous air is passed through the biofiltration, so the odourous compound are removed by the microbes growing on the media (Quigley et al., 2004).

The odour in form of compound are will be removed from the airstream or gases by absorbed and dispersion through the surface of the biofilter media or it also known as biofilm before leave to the atmosphere. Odourous compound will pass through process of digestion which called as bio-oxidation. This process occur when the compound digest the volatile organic compounds, gases and particular matter in presence of oxygen. The end products from these reaction such as biomass, mineral salts and water (Schmidt et al., 2004). The biofiltration process will result to reduce in odour emissions.

Biofilter media is one of the critical parts in biofilter design. The selection of the media should give more concern on it. Selection is critical because must think through and provides the suitable environment for maintain with high porosity and microbial growth. This condition must consider because to give a way for air to flow easily through this media. The properties that must include when media material selection is nutrient content, slow decomposition, porosity and moisture holding capacity (Schmidt et al., 2004). The voids in biofilter media should be 50 to 80 percent this to allow the flow of air to move easily (Chen, 2008).

According to the biofilter media use of wood chips and compost is good material as a media selection. The wood chips normally will support to the structural and also as a void space material. Next, the compost will give good nutrient rich to the environment and as an initial source of microorganisms. Research reported for this paper focused on the biofilter media selection for reduce of the odour emission from the palm oil mill effluent.

1.2 Problem Statement

Odour problem make the people around the oil palm production area causes nuisance problem throughout bad oxygen and it also sometimes brings to health problem. But there is lack of attention taken to the odour management or to reduce odour compound.

Biorid, the main and sole provider of odour biofiltration technology in Malaysia have installed more than 35 odour biofilters in Malaysia since 1999 (Excel Air., 2015). However, just a year after operation until now, two of the systems are known to still receive odour complaints. The undesirable condition of currently available biofilter technology and the high demand for odour treatment complement the objective of this study and make it even more important.

To reduce the odour nuisance problem biofiltration system is taken into consideration. Biofiltration system is a mature system for odour treatment and is get to be fully understood for use in Malaysia. The biofiltration process is managed by using biofilter media system. The media is the part of filter to odour. So, the media selection is one of main and important part in this biofiltration process.

Agricultural sector is the production of large quantities of processing residues that have no economic value other than energy generation. The presence of these residues in recent years has created a major disposal problem due to the fact that open burning is being discouraged by the Department of Environment in Malaysia (Abdullah and Sulaiman, 2013).

One of these wastes is palm oil compost. The amount which palm oil compost produced for every year could be helpful to use as alternative media for biofilter bed media. Next, the wood chips also one of the waste products at wood industries which normally at last will be burns it. The amount that wood chips produced also in large amount for every year which it could be helpful to use for biofilter bed media. The Wood chips support to structural and also as a void space material.

1.3 Objectives

The objectives of the research are as follows:

1. To determine the characteristic of wood chips and compost used for packing material in biofilter.
2. To identify suitable ratio of mixed media and operational condition for biofilter.
3. To identify Palm Oil Mill Effluent (POME) odour removal efficiencies at varying biofilter operational conditions.

1.4 Scope of Work

The study was generally focused on reducing the odour or air emission at Palm Oil Mill. Firstly, woodchip will be taken from wood factory at Changkat, Sungai Jawi, Pulau Pinang. Compost will be taken at United Oil Palm Industries Sdn.Bhd, 878, Jalan Bandar Baru, Sungai Kecil, Nibong Tebal, Pulau Pinang. The both media material focused to understanding the basic characteristics which is porosity test, bulk density test, moisture content test, water holding capacity test and pH test.

Then, 2 laboratory scale biofilter system will be developed to test three different operational condition which is pure media material using wood chips only, pure media material using compost only, and mixed media material using wood chips and compost.

Throughout, the research needs to take the collection of air sample for removal capacity of odour before and after pass the through media in biofilter. Next, scope of work is to understand the pressure drop test. As a last scope is to limit the Empty Bed Retention Time is 60 seconds for the biofilter in this research.

1.5 Dissertation Outline

This dissertation consists of five main chapters. So, every chapter explains with different parts of this study. Chapter One explains about background of the study, problem statement, objectives, scope of work, important and benefits of the study. Chapter Two focus on explaining for literature review which is about oil palm tree, palm oil mill effluent (POME), palm oil mill effluent treatment, biofiltration, bioscrubber, type of biofilter system, factor affecting biofilter performance, monitoring of biofilters performance and summary of literature review. Chapter Three provides the stages in methodology and some of the laboratory tests performed including its procedure. The results and discussion obtained from the laboratory test carried out including the tables, graph and figures in the chapter Four. At the end, Chapter Five concludes this dissertation and a future recommendation are added for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Palm Oil Mill Effluent (POME)

POME is one of the most polluting agro-industrial residues due to its high organic load. POME is normally in the form of dark brown colloidal slurry of water, oil and fine cellulose materials from sterilization and clarification stages. POME are acidic brownish colloidal suspension, characterized by COD (50,000 mg/L), BOD (25,000 mg/L) Oil & Grease (4000 mg/L) and high amount of total solids (40,500 mg/L) (Ahmad et al., 2003).

The production of the oil palm result in the generation of large quantities of contaminated wastewater usually referred to as palm oil mil effluent (POME). As normal, 5-7.5 tonnes of water are required for 1 tonne of CPO production (Rupani et al., 2010). One tonne of POME will be produced from every 2 tonnes of FFB processed from the mill (Yacob et al., 2005). POME contains variety of suspended components including an assembly of minor organic and mineral constituents, organelles, short fibres, range of nitrogenous compounds from proteins to amino acids, a spectrum of carbohydrates ranging from hemicellulose to simple sugars, free organic acids and cell wall (Oil, 2009).

2.2 Palm Oil Mill Effluent Treatment

There is about more than 85% of the POME treatment using ponding system and rest are focus on the open digester tank (Yacob et al., 2005). For the ponding system consists of de-oiling tank, acidification ponds, anaerobic ponds and facultative or aerobic ponds (Bala et al., 2014). The biogas will be released to the atmosphere and long retention time in excess of 20 days is needed for the ponding system. Generate 35% and 45% of CH_4 gas respectively by open digester tank and lagoon system.

Conventional POME treatment need the method whereby long retention time and large treatment area. High rate anaerobic bioreactors have also have been applied in laboratory-scaled POME treatment such as up-flow anaerobic sludge fixed film (UASFF) reactor (Bala et al., 2014); continuous stirred tank reactor (CSTR) (Poh and Chong, 2009); fluidized bed reactor (Bala et al., 2014); anaerobic contact digester (Ibrahim et al., 1985); up-flow anaerobic sludge blanket (UASB) reactor (Badroldin 2010); and up-flow anaerobic filtration (Borja and Banks, 1994). Other than that, aerobic activated sludge reactor (Vijayaraghavan et al., 2007), evaporation method (Rupani et al., 2010) and anaerobic digestion, membrane technology (Poh & Chong, 2009) also used to treat POME.

The anaerobic digestion system are being used significantly in wastewater treatment especially in agro-industry due to anaerobic digestion which has substantial advantages such as low energy requirements (no aeration), generates sludge from process which could be used for land application and producing CH_4 gas a valuable and product. In comparison with open digester tank, the anaerobic pond had a higher emission of CH_4 with an average CH_4 composition of 54.4% (Yacob et al., 2005). Gaseous mixture is the consistent for CH_4 composition from the anaerobic ponds.

2.3 Odour Treatment System

Odour treatment system is the system to reduce the odour problem around this environment. There are many type of odour treatment system but which discussed in this literature review are biofiltration, wetscrubber and membrane bioreactors.

2.3.1 Biofiltration

Biofiltration is in the situation of exhaust air treatment. Exhaust air treatment is a technology in which air is passed through a packed bed of warm, moist, nutrient-rich, porous filter medium prior to emission into the atmosphere. Normally, for the suitable environment for the growth of microbial films is provides from filter medium. According to the (Zhang et al., 2002) for the carried in the air stream diffuse into these films and are metabolized from any volatile compound, organic and some others.

Carbon dioxide and other non-odourous gases, water and mineral salts is principle of metabolites. Large volumes of air containing low concentration of contaminant compounds are used to treatment in the biofiltration process (Otten et al. 2004). Biofiltration is an one technology which use to reduce the odour in air emitted from livestock facilities (Nicolai and Janni, 2001).

The principles of a biofilter are similar to those of common biofilm processes. Basically, a three-step process occurs within the bed of a biofilter. First, a chemical in the gas phase crosses the interface between gas flowing in the pore space and the aqueous biofilm surrounding the solid medium. Then, the chemical diffuses through the biofilm to a bed of acclimated microorganisms. Finally, the microorganisms obtain energy from oxidation of the chemical as a primary substrate, or they metabolize the chemical via nonspecific enzymes.

Simultaneously, there is diffusion and uptake of nutrients, such as nitrogen and phosphorous in available forms, and oxygen within the biofilm. Utilization of the chemical, electron acceptors, and nutrients, continuously maintains concentration gradients driving diffusive transport in the biofilm. A properly designed and operated biofilter converts target waste gas chemicals to end products such as carbon dioxide (CO_2), water (H_20), inorganic salts, and biomass. The basic components of a biofiltration system are displayed in Figure 2.1. Waste gases often require pre-treatment to ensure successful biofilter operation.

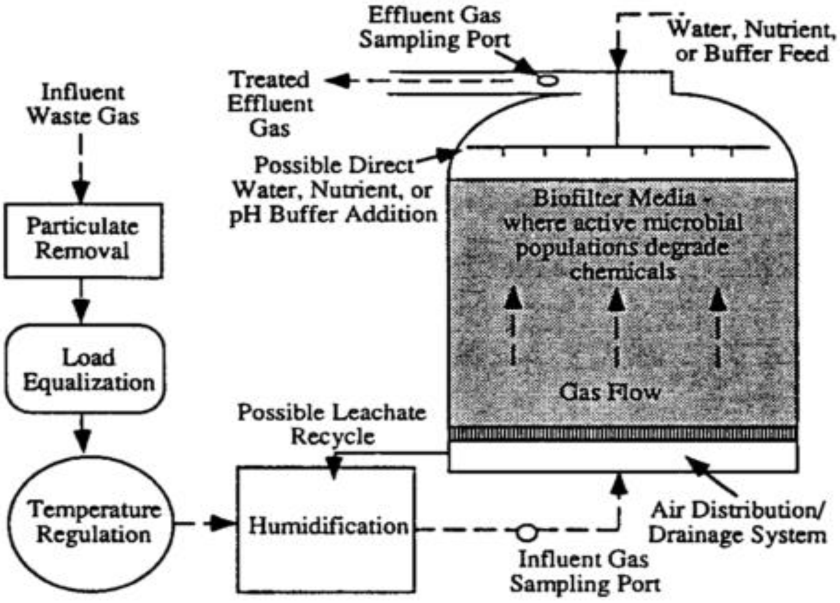

Figure 2.1: Schematic drawing of a biofiltration system (Kalingan et al. 2004)

2.3.2 Wetscrubbers

The wetscrubbers system is has some advantages over media based filtration. So, the wetscrubbers acts as a humidifier and degrades a high portion of the odour load (Schlegelmilch et al., 2005). This process is normally altered in the water of the reactor which it was easily controlled because of nutrient balance, removal of metabolic products, temperature and pH (Burgess et al. 2001). Moreover, buffering effect might be lead to a rise in temperature in the biofilter material due to increasing degradation process. Otherwise, it also could prevent high concentration of odourous substance from entering the biofilter (Schlegelmilch et al., 2005).

The disadvantages of this system focus on a major consideration where as many air pollutants and poorly water-soluble and odourants are volatile. Other than that, to reduce solid waste output and to increase gas treatment efficiency the wetscrubber biomass has to be controlled. So, the biomass reduction can be done in two ways which is decrease efficiency of energy generation for biomass growth by limiting nutrient supply (Burgess et al., 2001). Second is increasing the requirement for maintenance energy by increasing the mean cell residence time (Burgess et al., 2001). From this wetscrubbers are less popular than biofilters, because of some features.

2.3.3 Membrane Bioreactors

In this method, the pollutant gas will be change into liquid. There are two type of membrane are used in this system which is dense material are more selective such as silicone rubber. Second is hydrophobic microporous more permeable such as polysulphone (Burgess et al. 2001). Normally, mass transfer coefficient inside a dense membrane depends on the solubility and diffusivity of the material matrix. Treatment system of indoor air already been tested by membrane prevents microorganisms from contaminating the gas phase (Burgess et al. 2001). This is because the gas can be used as carbon or nitrogen source which microorganisms in the liquid phase. But through the previous study membrane bioreactors for odour treatment does not yet tested for a full scale.

2.4 Types of Biofilter System

Odourous air is cleansed in biofiltration according to the microbial activity is the primary mechanism. To get the appropriate microbes by maintaining preferential conditions the effectiveness of a biofilter is maximized. So, the effectiveness of the biofilter is perform by include the temperature, nutrient availability, moisture and acidity. These conditions are depending on the differential kind of the microorganisms which are intended to colonize the filter medium.

Normally, to the new biofilter it will take time to stabilize the appropriate operating conditions for good microbial growth. There is usually acclimation period of up to several weeks in which the odour removal in the samples start with low conditions and gradually improve, when or during the start-up of the new biofilter (Zhang et al., 2002). Once established, however microbial activity is usually sustained with minimal inputs except an appropriate waste air stream and perhaps some supplemental moisture (Zhang et al., 2002). The biofilter bed of reasonable size can maintain the temperature even at the climate of cold by microbial activity is exothermic.

In the compost or soil biofilters common in livestock operations, the accumulation of microbial biomass will eventually clog pore spaces in the filter medium. The reducing of efficiency for the biofilter through the clogging limits airflow, as well as nutrient and water transport to the microbes (Zhang et al., 2002). Such biofilter are therefore considered to have an effective operating life of about three to five years because operating conditions degrade at about this time, and the filter medium must therefore be replaced (Zhang et al., 2002).

Biofilter can be classified in several ways and it will be depending on the layout. Biofilter can be either in the type of open-bed biofilter, closed-bed biofilter, or trickling biofilter:-

2.4.1 Open-Bed Biofilter

This biofilter are the most common type used to treat air from animal facilities, is an in-ground or on-ground, open-bed filter of compost and wood chips (Zhang et al., 2002). The media which in the open-bed biofilter is uncovered and exposed to weather conditions, including rain, snow and temperature extremes. There is also can have roof over the biofilter to provide some weather protection. Normally, these types of biofilter are the least expensive type which according to initial investment and operating cost (Tuhkanen et al. 2012). The open-bed biofilters are displayed in Figure 2.2.

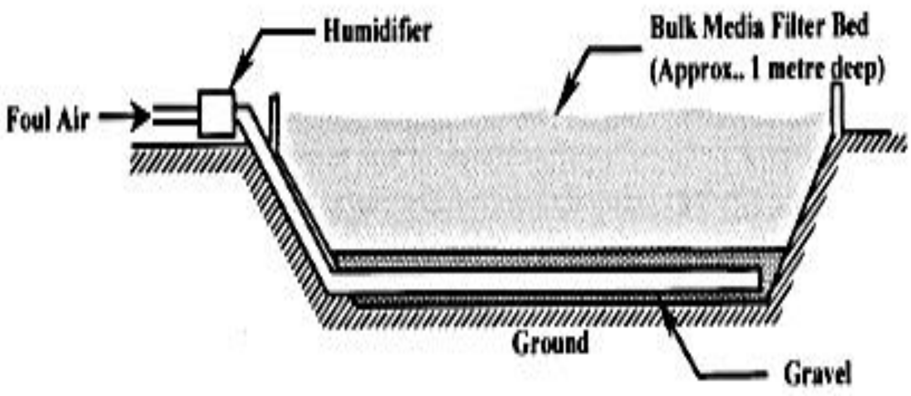

Figure 2.2: Open-Bed Biofilter (Burgess et al., 2001)

2.4.2 Closed-Bed Biofilter

This type of biofilter is mostly will be enclosed with small exhaust port for venting of clean air. Other than that, these types of biofilter are generally more expensive to construct, operate and maintain than open-bed system (Burgess et al., 2001). So, closed-bed mainly can arrange for more effective removal of odour and contaminants. Closed-bed biofilter also can give more effective operating parameters such as humidity, filter-bed moisture and temperature. This type of biofilter is used for treatment in smaller air flow rates than generally occurs in the swine industry. The closed-Bed Biofilter are displayed in Figure 2.3.

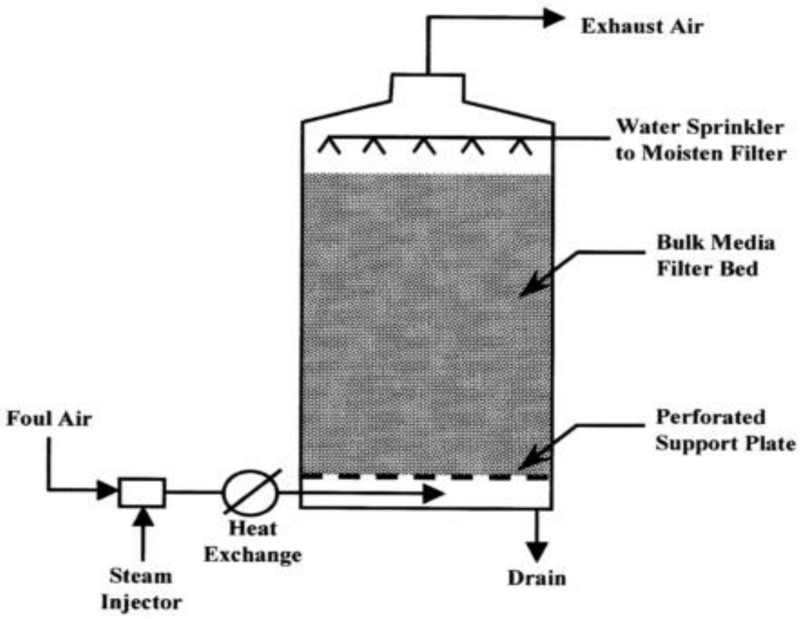

Figure 2.3: Close-Bed Biofilter (Burgess et al., 2001)

2.4.3 Trickling Biofilter

The odour-laden air stream is passed over a microbial consortium immobilized on support media with a high surface area. Recirculating water maintains humidity in the media bed and allows nutrient supply. Odourants dissolve into the aqueous phase and are degraded by the biofilm present. Foul air can pass through a trickling biofilter either co- or counter-currently to the liquid that provides the biofilm with nutrients.

Trickling filter media can be ceramic or plastic structures, activated carbon, celite, or mixtures of materials (Chen et al., 2015). Filters in which the foul air is recycled, moderate dissolved oxygen (DO) is maintained throughout, and the wastewater does not short-circuit through the media are the most effective for odour treatment. Trickling biofilters represent a method in which reaction products are washed out of the media and acidification can be avoided.

The major drawback with this system is the problem of transferring the odourous pollutants from the foul air to the liquid phase, but trickling biofilters can still be effective in treatment of gaseous compounds with an air/water partition coefficient of less than 0.1 (Prado et al., 2009).

However, it has also been shown that decreasing the liquid flow rate to the minimum required for microbial growth can result in more efficient gas treatment, and also avoid one operational problem specific to trickling biofilters; the accumulation of excess biomass in the media bed (Prado et al., 2009).

Excess biofilm can completely clog a filter bed, although this does not always occur and can also be prevented by liquid nutrient minimization and backwashing. However, long-term minimization of liquid supply leads to reduced microbial activity and gas treatment, so backwashing is a better option for maintenance of filter media (Burgess et al., 2001).

A study by Iranpour et al. (2005) on biotrickling biofilters at Privately Owned Wastewater Treatment Plant (POWTs) shows that performance data for biotrickling filters indicate that these reactors are capable of efficient removal of high concentrations of Hydrogen Sulphide, H_2S at relatively low Empty Bed Contact Time (EBCT).

Thus, bio trickling filters appear to be a good option when the gas to be treated contains high concentrations of H_2S and possibly other reduced sulphur compounds. The studies that included VOCs indicate that, although H_2S removal may be faster in bio trickling filters, the VOC removal is in general lower than that in biofilters. The trickling biofilter for odour control are displayed in Figure 2.4.

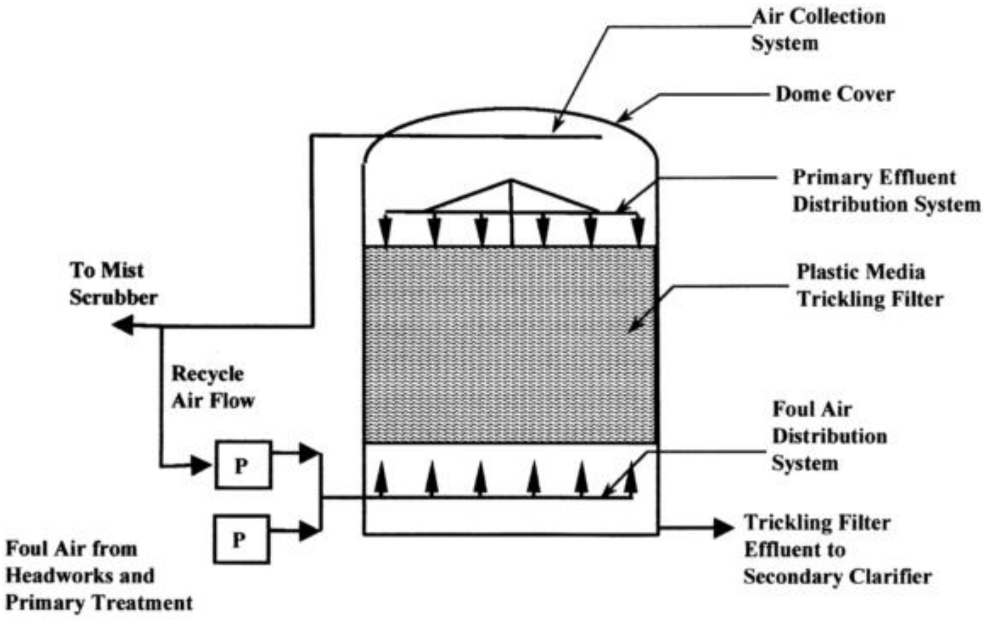

Figure 2.4: Trickling Biofilter for Odour Control
(Burgess et al., 2001)

2.5 Factors affecting Biofilter Performance

Biofilter performance is one of the important parts which to maintain and get better results in removal efficiency. There is many factors that affecting the performance of the biofilter . So, here some of the factors are been discussed which is biofilter media, moisture content, empty bed retention time (EBRT), temperature, media depth, biofilter longevity and microbial activity.

2.5.1 Biofilter Media

The selecting of the biofilter media in biofilter is the main and important step. The desirable media properties include:

1. Suitable environment for microorganism to thrive including enough nutrients, moisture, neutral pH, and unlimited carbon supply (Chen and Hoff, 2009);
2. Reaction site for per unit media volume are focused on large surface area to maximize attachment area, and sorption capacity;

3. To resist media compaction and channelling need to stable the compaction properties;
4. To keep higher absorption ability and active microorganisms needed high moisture holding capacity;
5. High pore space to maximize EBRT and minimize pressure drops;
6. To reduce media compaction potential, then needed the low bulk density.

The above media properties have been pointed by (Chen and Hoff, 2009). The most used or chosen media are organic material such as peat, wood chips, compost, bark mulch and mixtures of these. So, each of the materials have many of the qualities mentioned above, with the main drawback being degradation of the organics comprising the bed. The compaction and a limitation on the bed life are leaded from degradation phenomenon.

Extra operation expense, increase porosity and can modestly improve performance, an organic material eventually will require replacement through periodically turning media (Chen and Hoff, 2009). Plastic saddles, and shredded high density plastics is one of combining organic material with inert bulking agents. Perlite and vermiculite can increase biofilter porosity can increase biofilter porosity, minimize pressure drop, compaction and channelling, resulting in a longer useful life (Chen and Hoff, 2009).

To maintain needed activity of the biofilter microbes, so an ideal solution in most applications is to use only the necessary amount of easy-degradable organic matter in the mixture media (Chen and Hoff, 2009). Studies are needed to determine the optimal ratio of easy and hard or non-degradable media materials for various applications. A mixture of compost and wood chips at a ratio of 30:70 as agricultural media (Hort et al., 2009). Chen et al. (2008) showed that wood chips alone can successfully be used to treat odour and VOCs exhausted from a deep pit swine building. Agricultural uses also have other media choices for local availability.

2.5.2 Moisture Content

The moisture content in the biofilter media is one of important parameter for biofilter operation and also with the residence time (Schlegelmilch et al. 2005). Goldstein (1999) pointed that 90% of the cases for failure is depends on the media drying. Maintaining moisture during operation conditions is the difficult part in biofilter.

The factors of complicated maintenance of optimal medium moisture levels, and methods for maintaining optimal media moisture content which effects of over wetting and dry media (Swanson and Loehr, 1997). The optimal range of the moisture contents is depends on the biofilter media. The 50% to 55% moisture was a good target range for compost-based media (Nicolai and Lefers 2006). Chang et al., (2004) pointed that a media moisture content of 60% to 80% was proper for a pilot biofilter packed with chaff of pine and perlite.

The efficient pollutant reduction using a mixture media of compost and wood chips which recommended moisture range of 35% to 65% (Nicolai and Lefers, 2006). The mitigating odours and VOCs from deep pit swine finishing building when wood chips were used as the biofilter media and moisture content level is 40% to 60% (Chen et al., 2015). The wood chips moisture content of greater than 63% be used to maintain overall efficiency (Chen and Hoff, 2009).

Maintenance of moisture content is based on precise measurement. Several researchers used gravimetric method to monitor the moisture content (Kala et al. 2009).

This is the oldest method but it will not suitable for continuously monitoring. Media moisture content will be calculated by continuously weighing the biofilter known as load cell method (Chen and Hoff, 2009).

The moisture content of biofilters to be controlled to ± 4%, if the weight of the biofilter was known. The problem for a weight-based method because almost all agricultural application need to deal with dust (Nicolai and Lefers, 2006). Time domain reflectometry (TDR) probe could be used to monitor their biofilter media moisture content on a real-time basis (Chen and Hoff, 2009).

TDR probe are used to measure the vertical moisture content profile in peat columns which determined gravimetrically and consistent discrepancy between the TDR measured moisture content (Chen and Hoff, 2009). Five different types of moisture meters in a typical biofilter media and concluded that the soil and hay moisture meters they tested were unsuitable for measuring the media moisture content due to the variability and limited range of the meters' response. To monitoring media moisture content which relative humidity sensor are tested.

The capacitor sensor which used to testes is worked well over a wide range of the frequencies and biofilter media moisture content. Lefers and Nicolai, (2005) recommended that watermark moisture content sensor and a moisture control system were tested in a laboratory-scale biofilter.

The water supply is to maintain the moisture in the media, so at laboratory the circulate leachate continuously or intermittently. The water are supply through spray nozzles which by manually or controlled by a timer to irrigate the media surface during on-site studies. If the water are supplied manually this probably contributed to the failure of optimal media moisture control.

The optimal period of water supply needed to be tested and given proper airflow rate and atmospheric conditions which is for both manual and timer. To keep wood chips moisture content at 60% to 70% that supplied 9-s water using a solid cone mist nozzle controlled automatically via solenoids at adjustable time periods between 30 and 50 min (Chen et al., 2015). Through this the result show that the water consumed was half compared to a manually controlled method previously tested in the same situation.

2.5.3 Biofilter Empty Bed Retention Time (EBRT)

Theoretically, microorganisms living in the biofilter will degraded the pollutants in the gas phase to be transferred to liquid phase. EBRT is critical design and operating parameter which to get a sufficient EBRT is necessary to allow the transfer and degradation of pollutants (Chen et al. 2015). Gas residence time is relative measure to the EBRT within to biofilter media. The result to the EBRT divided by the air-filled porosity available for gas flow which the actual gas residence time for the biofilter reactor but such porosity data is rarely known (Chen and Hoff 2009).

So, different EBRTs to be completely degraded because different pollutants have different characteristics which affect the absorbing and adsorbing times and degradation processes. The media moisture content and pollutant loading are will be related to the reasonable EBRT. For a shorter EBRT results from higher moisture content and lower pollutant loading. Sufficient odour reduction at 10 s for covered manure storage units, 5s for swine barns and 3 s for chicken farms (Schmidt et al. 2004). Janni et al. (1998), Nicolai and Janni (1998, 1999) showed that a 4 s EBRT was estimated adequate for swine nursery barns. Characteristic odourants removal at a deep-pit finishing swine building when wood chips media moisture content was maintained at 60% and 4 s EBRT will be the reasonable (Chen et al., 2015). Schmidt et al. (2004) recommended that design EBRT for a biofilter on diary and swine facility was given at 5 s for adequate odour and H_2S reduction.

2.5.4 Temperature

For efficient biofilter the optimal temperature are the best to enhance the microorganisms' activity results. According to the Easter et al. (2005), if higher temperature kills the microbes while lower temperature slow the microbial activity. Easter et al. (2005) recommended that for biofilter operated at the range of 20°C to 40°C, even at 35°C will be best or optimal temperature for the aerobic microorganisms in biofilters. Other than that, suggested an optimum operating temperature between 30°C and 40°C (Zhang et al. 2002).

Effects of operating temperature and supplemental nutrients in a pilot-scale biofilter have investigated (Canovai et al. 2004). Through their data suggested or investigated which higher operating temperature accelerated the establishment of microbial population and the onset of effective biofiltration. There is also will does not have any significant difference for overall odour removal could be associated with different treatment temperature ranging from 15°C to 30°C.

The biofilter which packed with a combination of compost and wood chips are investigated through effects of two different inlet temperature (13°C and 22°C) (Nicolai and Lefers, 2006). They summarized it by raising temperature increased average removal efficiency. Mann et al. (2002) investigated that an open biofilter used to treat odour from a swine barn during sub-zero ambient temperature. The use of insulated open biofilters without supplemental heat can be effective even the ambient temperatures were below -20°C were suggested when the odour concentration reduction ranged from 56% to 94%.

Temperature effects on biofiltration of off-gases showed biofilter material worked better at a temperature warmer than 10°C summarized by Chen and Hoff, (2009). As a same biofilter systems should be operated at a temperature above 10°C (Nicolai and Lefers, 2006). Schmidt (2004) also have been discussed that temperature variation is helped to microorganisms often recover rapidly, but even non-optimal temperature can slow down the microbial activity. Lehtomaki et al. (2004) showed that biofilter which experienced a 10 day shutdown period resulting in a media temperature of 4°C which through a RE of 80% to 90% was immediately achieved after receiving 30°C waste gas.

2.5.5 Media Depth

The most between depths is 0.3 to 0.75 m have been commonly used for on-site biofilter and other ranging from 0.3 to 1 m. The main factor to affects pressure drop and removal efficiency will be biofilter media depth, along with air flow rate. The pressure drop decreased with decreasing media depth while maintaining constant surface area which showed from the effect of biofilter retention time on emissions. The removal efficiency of odour reduced below 65% with reducing residence time by lowering depth below 0.15 m (Chen and Hoff, 2009). So, the ideal depth of the compost/wood chips media suggested is 0.25 m which is between 0.15 and 0.3 m.

Khammar et al. (2005) showed that between 0.3 and 1m in depth for two pilot-scale biofilter are spatial structure of microbial communities in peat media indicated that 75% of the 95% RE and 55% of the 80% RE for aromatic compounds. The height of the biofilter packing with a mixture of peat, perlite and vermiculite, and the relationship between NH_3 RE was investigated (Chen and Hoff, 2009). The media depth of 0.25 to 0.45 m for biofilters used in agriculture to keep balance between acceptable RE and pressure drop (Schmidt et al. 2004).

2.5.6 Biofilter Longevity

The results in biofilter failure which lead from media compaction, smaller surface area, higher pressure drop, chemical accumulation and this all are proceed with time of media degradation (Saliling et al. 2007). The same microorganisms degraded from odourous compounds and biofilter media as results of their activity. The media type, microbial activity and dust loading is relies from longevity of biofilters.

Higher population of microorganisms is produced where if the media with a higher percentage of compost and it will result in higher odour RE making it useful for controlling higher concentration of odourous pollutants. The shorter lifespan is resulted through degrades and compact faster (Goldstein, 1996). If a media with smaller percentage of compost will degrade slower while maintaining optimum odour removal results and a lower concentration of odourous compounds presented in the air stream.

Chen, (2008) pointed that to meet RE expectation by a mixture with a minimum portion of easy-biodegradable materials that can support necessary microbial activity for lasting longevity. The high dust loading fills the pore spaces faster than the microorganisms can break it down and it could make the biofilter to fail. The agricultural can be used pre-filter dust to keep from plugging pore spaces within biofilter. The air handler resulted in biofilter failure and air quality challenges for the animals due to a reduction in ventilation capacity are damaged when pore spaces plug, the pressure drop builds sharply.

The longevity can be extending when a media is remixed with a drawback of spending extra money. The most biofilter media will remain effective with acceptable pressure drop for three to five years or more but cannot handle the studies on agricultural biofilter for long-term to determine length of media life (Nicolai & Lefers, 2006). More than a three-year life expected (Chen and Hoff, 2009).

2.5.7 Microbial Activity

Microbes will degrade compounds in waste gases because the biofilter are living systems. The changes in a microbial community structure during a 120-day operation of a biofilter for treating ammonia (Chen and Hoff, 2009). The decreases were occurring to 38% at the end of the studies when overall diversity of the heterotrophic microbial population appeared. The changes occur from predominantly members of two subdivision of the Protrobacteria to members of one division which by community structure of the heterotrophic population. The observation was not able to conduct because overall decrease in the diversity of ammonia mono oxygenate.

The seeding compost-based biofilter has not been demonstrated to improve performance in removing easily degradable chemicals (Swanson and Loehr 1997). Bohn (1992) recommended that the microorganisms indigenous to compost likely outcompete the seeded cultures. A number of authors have suggested in attempts to reduce acclimation time and use of activated sludge as a seed for improving removal efficiency (Chen and Hoff, 2009).

Investigated links between spatial structure of microbial community and degradation of a complex mixture of volatile organic compounds in peat biofilters by Khammar et al. 2005. They have been summarized that microbial diversity was maintained and structuring of microbial community in terms of the biodegradation activity and microbial community adapted to a new environmental conditions. The specialization of microbial density and diversity occur or correlated from the distribution of biodegradation activities.

The changes in the bacterial community of a compost biofilter treating H_2S and it indicated that the microbial population existing in the biofilter after 20 days was less diverse when H_2S was the only substrate by Ding et al. 2006. Other than that, introduction of methanol (CH_3OH) resulted in the enrichment of a variety of CH_3OH and H_2S degraders, thus enhancing the microbial community which resulted in enhanced degradation.

2.6 Monitoring of Biofilter Performances

There are many processes or factors to monitoring biofilter performances which is removal efficiency of odourous compound, removal efficiency of odour, pressure drop, pH and nutrients.

2.6.1 Removal Efficiency of Odourous Compounds

Nicolai et al. (2006) pointed that most odour and gas emissions transformation of organic matter in manure by microorganisms and manure storage sources are by-products of anaerobic decomposition. Chen et al. (2008) also showed the results in a complex mixture of over 168 volatile compounds of which 30 have a detection threshold of 0.001 mg/m3 or less, and hence are most likely to be associated with odour nuisance. There also have been identified about 294 compounds emitted from swine manure which cover broad spectrum and generally exist in low concentrations by Lo et al. 2008.

Chen and Hoff (2012) and Janni et al., (2001) which recommended biofilter have the ability to treat abroad spectrum of gaseous compounds. According to