ISSN: 2521-0904 (Print) ISSN: 2521-0440 (Online)



Contents List available at RAZI Publishing

Engineering Heritage Journal / Galeri Warisan Kejuruteraan

Journal Homepage: http://www.razipublishing.com/journals/galeri-warisan-kejuruteraan-gwk/https://doi.org/10.26480/gwk.01.2017.45.48





Biomass as Packing Material for Biofiltration of Gaseous Streams

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ARTICLEDETAILS

Article history: Received 12 August 2016 Accepted 20 November 2016 Available online 10 January 2017

Keywords: packing materials; biofiltration; characteristics; biomass

ABSTRACT

Biofiltration has quickly become an effective choice for treating odorous air streams as well as air emissions because of the improving reliability of these systems and also because of its reputation as a type of green technology with no hazardous residue and no utilization of chemicals. As odorous air flow through the system, the air compounds are oxidized by the microbes growing on the biofilter media. Four local biomass packing materials to be used as support media in biofiltration are analyzed and compared to evaluate their suitability according to physical and chemical characteristics. The characteristics of the packing material in biofilters is an important factor for the success in the biofiltration's construction and operation. A set of six different parameters were selected to test the selected packing materials such as porosity, spesific density, surface area, water holding capacity, moisture content, pH and purchase cost. Since biofiltration success generally depends on a combination of several parameters either from the system or the materials choosen, a procedure was defined to compare packing materials suitability under common situations in biofiltration. The results indicate that, out of the packing materials studied, palm kernel shell and wood chip were ranked on top of several parameter rankings and showed as a significantly better packing materials when parameters were combined.

1.0 Introduction

Biofiltration utilizes microorganisms immobilized on a biofilm existed on the surface the filter material chosen for the biofilter. Till now, biofilters have shown that odorous effluent gases of low concentrations can be processed at low operation and maintenance costs. It involves microorganisms immobilized in the form of a biofilm on a porous carrier, such as, peat, soil, compost, synthetic substances or combinations of them.

Table 1. Biological conversions important in biofiltration of odorous

| Type of bacteria | Transformati | Oxygen |
|--------------------|------------------------|-------------|
| | on | requirement |
| Chemoheterotrophic | Organic | Aerobic |
| bacteria | carbon | |
| | oxidation | |
| | VOC →CO ₂ , | |
| | H ₂ O | |
| | | |

| Nitrifying bacteria | Nitrification | Aerobic |
|-----------------------|-------------------------------------|---------|
| | $NH_4+\rightarrow NO_2^-$, | |
| | NO ₃ ⁻ | |
| Sulfur oxidising | Sulfide | Aerobic |
| bacteria | oxidation | |
| | $H_2S\rightarrow S_0$, SO_4^{2-} | |
| Denitrifying bacteria | Denitrification | Aerobic |
| | $NO_3^- \rightarrow N_2$ | |

As the polluted air stream passes through the filter bed, pollutants are transferred from the gas stream to the biofilm developing on the organic substrate. The microorganisms then oxidizes the pollutants into clean air [1-3].

In this study, the characteristic of four biofilter packing material to treat polluted gaseous streams was examined and characterized as potential carrier material in biofilters.

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1.1 Characteristics of biofilter packing material

Since the removal of odour occurs within and through the packing materials of the biofilter, the packing materials is essentially an important factor determining the characteristics and the efficiency of odour gas removal within the system. Almost all organic compounds can be utilized as a biofilter packing material [5]. An organic media mixture of compost and wood chips or wood shreds was reported often for the use in odour biofilters. These mixes consist of mixture ranges from approximately 30:70 to 50:50 ratio by weight. The compost in the mixture provides microorganisms, nutrients, and moisture holding capacity. The wood on the other hand, provides the porosity [6]

1.2 Palm Oil Biomass

Oil palm is one of the most valuable economy in Malaysia, Indonesia and Thailand. Malaysia is a large producer and exporter of oil palm, producing 60% of the world's oil and fat production. [8].

Oil palm production has nearly doubled in the last decade, and oil palm has been the world's foremost fruit crop, in terms of production, for almost 20 years. Oil palm industries generate abundant amount of biomass say in millions of tons per year which when properly used will not only be able to solve the waste disposal problem but also produce value added products from the biomass. [9]

The biomass from oil palm residue include the oil palm trunk (OPT), oil palm frond (OPF), kernel shell, empty fruit bunch (EFB), presses fruit fibre (PFF), and palm oil mill effluent (POME). Oil palm fronds accounts for 70% of the total oil palm biomass produced, while the EFB accounts for 10% and OPT accounts for only about 5% of the total biomass produced [10].

It was reported that oil palm biomass burnt as fuel in the boiler to produce steam for electricity generation in the processing of oil palm. Researchers stated that a large amount of oil palm residues resulting from the harvest can be utilized as by–products, and it can also help to reduce environmental hazards [11].

1.3 Compost and wood chip in biofilter

Compost has many of the qualities mentioned above, with the main drawback being a relatively fast degradation, which leads to compaction, a limitation on bed life, and a high airflow resistance that must be overcome with the use of large, expensive fans. The mixture of wood chips and compost has been recommended as biofilter media for agricultural uses; however, special care is needed to screen fines from wood chip/compost mixtures to reduce operating static pressure. To keep reasonable fan ventilation efficiency, agricultural ventilation fans should be run at pressure drops of less than 60 Pa. Using only wood chips as biofilter media can reduce the pressure drop without special fan needs, which results in less construction and operating costs. [12].

2.0 Materials and method

2.1 Research Material

Empty Fruit Bunch (EFB) and Palm Kernel Shell were obtained from United Oil Palm, a palm oil mill in Bandar Baharu, Kedah. Organic composts made of EFB were obtained from Green Earth Holdings, a company specializes in making organic fertilizers in Malaysia located in Selangor. The softwood wood chips tested were obtained from Unipalm Manufacturing, a wood pellet company situated in Johor. All materials were tested raw with no sieving.







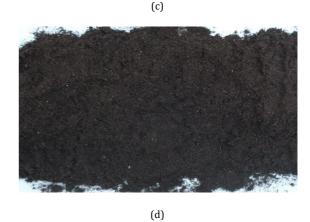


Figure 1 Four type of biomass (a) Palm Kernel Shell; (b) Empty Fruit Bunch; (c) Wood chip; (d) EFB Compost

2.2 Experimental Tests

All materials selected for the research were analysed for water content, density, porosity, specific surface area, pH, and water holding capacity. The media moisture content was calculated by using standard method by taking the average of sample moisture from different depths, and was measured by oven-drying at 105° C for 24 hours. Three replications were completed and the average value was recorded.

To measure bulk density of the materials, a standard test for bulk density is conducted. An empty 20 L pail was weighed on a scale and the mass was recorded. The container was then filled with the test material and the mass of the material was recorded. Bulk density was calculated by dividing the mass of the material by the volume of the material. Three replications were completed and the average value was recorded.

The five-gallon pail method was used to determine the porosity of the media mixtures. The volume of water added was recorded [13].

For determining moisture content, all filter materials were dried to equilibrium moisture content in a dry-kiln for 24 hours. For WHC, containers were used to hold the materials while they were submerged in water for 1 day. Three replications were made for each sample. Absorptive capacities were determined on the basis of the weight gained divided by the kiln-dry weight of the sample x 100 after 24 hours submergence time.

The pH of each of the materials were determined by using a calibrated meter Eutech pH700. The specific surface area of the materials chosen were determined by Micromeritics ASAP 2010 volumetric sorption analyzer with nitrogen flow at temperature -110°C and was calculated using (Brunauer, Emmett and Teller) BET method.

3.0 Results and discussion

Table 2 shows parameters inherent to the material, allowing for comparison of the parameters on material porosity, density, specific surface area, water content, WHC and pH.

Porosity, and bulk density essentially relate to the same property of organic bed media and are important primarily for the effect they have on the gas phase pressure drop across the bed. Porosities for organic media range from 40 to 50% for soils and 50–80% for compost. Porosities for all tested materials falls within the range of 50-90% which is a good range for biofiltration usage.

Density of EFB however is really low at $0.071\ g/ml$. While the porosity is good for lowering pressure drop, lower density means the media is very susceptible to compaction and this may cause the pressure drop to increase.

EFB presented with the highest specific surface area while wood chip is the lowest. A high specific surface area around 1.2 m2 /g similar to a research on coconut fiber by Baquerizo et.al [14] is a favorable characteristic for biofiltration which can help in assisting in pollutant degradation.

WHC of the materials as presented in Table 1 can absorb up to 2 to 4 times its own dry weight. Other than that, water holding capacity of carrier is important, especially in gas biofiltration, as the gas passing through the carrier has a large drying potential. So a moistened filter bed containing these materials can lose up too much moisture before a lack of moisture will slow down microbial activity.

 Table 2. Characteristics of selected biomass.

| | Wood Chip | EFB | Palm Kernel Shell | EFB Compost |
|----------|---------------------------|---------------------------|---------------------------|---------------------------|
| рН | 6.92 | 8.20 | 7.40 | 6.20 |
| Porosity | 74.4 (<u>+</u> 3.5) % | 95.1 (<u>+</u> 1.6) % | 65.4 (<u>+</u> 1.9) % | 55.0 (<u>+</u> 2.6) % |

| | 0.479 | 0.071 | 0.600 | 0.800 |
|----------|-------------------|-----------------------|-------------------|-------------------|
| Density | (<u>+</u> 0.18) | (<u>+</u> 0.05) | (<u>+</u> 0.12) | (<u>+</u> 0.09) |
| | g/ml | g/ml | g/ml | g/ml |
| | | | | |
| Surface | 0.8665 | 1.1696 | 2.9623 | 1.2415 |
| Area | m ² /g | m²/g | m^2/g | m^2/g |
| | | | | |
| WHC | 250 | 400 | 380 | 200 |
| WIIC | (<u>+</u> 21.1)% | (<u>+</u> 13.6)% | (<u>+</u> 33.5)% | (<u>+</u> 23.1)% |
| | | | | |
| Moisture | 10 (±1.2) % | 40 (±3.7) % | 10 (±1.5) % | 10 (±4.0) % |
| Content | 10 (-1.2) 70 | 10 (<u>+</u> 5.7) 70 | 10 (-1.5) 70 | 10 (-1.0) 70 |
| | | | | |
| | 50\$ per | 180\$ per | 50\$ per | 170\$ per |
| Price | metric | metric | metric | metric |
| | tonne | tonne | tonne | tonne |
| | | | | |

As for most aerobic biological processes, optimal pH for biofilter operation is in the 7-8 range to facilitate maximum microbial activity required for maximum odour control [15]. Biofilters are not designed with continuously cycling liquid streams to washout acids, special provisions must be made to treat chemicals whose biodegradation results in acid end products.

For example, in a research by Leson and Winer, acetic acid was neutralized in a full-scale biofiltration installation with sodium bicarbonate addition to irrigation water [16]. In this study, most materials fall near neutral pH which will help to slow acidification of the system from the acid end products.

Like most biomass waste, all of the materials tested can be readily and easily obtained with little financial use. These materials are cheap which help reduce greatly the cost needed for replacing the materials after a few years.

4.0 Conclusion

A comparison of characteristic of packing materials consist of EFB, Palm Oil Kernel, EFB compost and wood chip as a carrier in biofiltration process with those reported in the literature showed that, all of the is expected to be an effective and cheap alternative of raw material of carrier for biofiltration systems. They have high density, suitable pH at near neutral, a large WHC, and no significant clogging risk with high porosity. Palm Kernel Shell has the best parameters to be used in a biofiltration procedure.

Acknowledgements

The authors would like to acknowledge Universiti Sains Malaysia for their financial support through the Research University Grant (RUI) under grant 1001/PAWAM/814236

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