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Effect of Secondary Parameters on Biofilter treating Industrial Effluent

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Abstract: This investigation reports that the influence of microbial inoculation on degradation efficiency for various secondary parameters such as bed temperature, moisture content and pH of Biofiltration column. Mixture of compost and woodchips is used as biofilter bed material with three different ratios namely 2:1, 1:1 and 1:2 having a porosity value of 0.32, 0.39 and 0.44 respectively. The height and diameter of the bio filtration column used in this investigation are 110 cm and 5 cm respectively. The height of bed materials are varied to 50 cm, 65 cm and 80 cm. The effect of bed temperature was monitored for different bed ratios the overall range lies between 28°c and 35ºc, the Moisture content of the bed was tested for various bed ratio the overall moisture content range lies between 40% and 60%. The pH of the bed was monitored that they were also in the optimum range between 6.5 and 8.5.The results showed a significant dependence of the degradation efficiency on the packing material, with highest removal efficiency above 90 % was observed.
Key words: Bio filtration, Bed temperature, Moisture content, pH, Compost and Woodchips.

INTRODUCTION

A large quantity of volatile organic compounds (VOCs) is released from various industrial sources such as the printing and coating, plastics, refrigerant, electronics and paint manufacturing[1]. In air pollution, bioreaction is simply the use of microbes to consume pollutants from a contaminated air stream. Almost any substance, with the help of microbes, will decompose (decay) given the proper environment. This is especially true for organic compounds. But certain microbes also can consume inorganic compounds such as hydrogen sulfide and nitrogen oxides. The capital cost of a bio reaction installation is usually just a fraction of the cost of a traditional control device installation and operating costs are usually considerably less than the costs of traditional technology, too. Thermal and catalytic control units consume large volumes of expensive fuel. Bioreactors only use small amounts of electrical power to drive two or three small motors. Normally, bioreactors do not require full-time labour and the only operating supplies needed are small quantities of macronutrients. Biofilters, the most common type of bioreactor, usually use beds (media on which microbes live) made from naturally occurring organic materials (yard cuttings, peat, bark, wood chips or compost) that are slowly consumed by the biomass (i.e., microbes). These organic beds usually can supply most of the macronutrients needed to sustain the biomass. The beds must be replaced every 2 to 5 years[2], depending on the choice of bed material. Bioreactors do work, but microbes are finicky in what they will eat. Microbes need the right pollutant concentration, temperature, humidity and pH. Variables that affect the operation and efficiency of a bioreactor include: temperature, pH, moisture, pollutant mix, pollutant concentration, macronutrient feeding, residence time, compacted bed media, and gas channelling. These are crucial variables for which optimum conditions must be determined, controlled and maintained[3].

Key factors influencing biofilter performance are the amount of time the odorous air spends in the biofilter (contact time) and the moisture content of the filter material [4]. In fact, lack of control over media moisture has been cited as the cause of up to 75% of all biofiltration problems[5]. Dry media causes channelling and leads to a decrease in biological activity. Media drying is especially a problem in the summer, when an increase in temperature raises the water capacity of the air, causing a faster evaporation rate of water from the media[4]. Biofilters with higher moisture contents and longer retention times were shown to have the best removal of both ammonia and hydrogen sulphide [6]. To sustain high removal efficiency, parameters such as water content, nutrient concentration, pH, inlet air relative humidity, and temperature should be controlled[7]. Moisture content has also been shown to have an effect on the pressure drop through biofilters [8].

Pressure drops are higher when moisture content is higher. However, this effect is only noticeable on low compost to wood chip ratios, and is not a major factor on pressure drop through media that consists of high compost to wood chip ratios.

Biofilter media moisture control is essential for odour reduction through a biofilter. Inadequate moisture can allow the media to dry out, deactivating the microbes, and creating cracks and channelling of air which results in a reduction of filter efficiency. Too much moisture can plug some of the pores in the media, causing channelling and limiting oxygen flow in saturated areas of the filter, thereby creating anaerobic zones in the bio film[9]. Excess moisture is generally not a problem because the additional moisture drains through the media or evaporates due to the constant airflow through the bio filter. Recommended moisture contents for bio filters range from 40 to 65% wet basis (w.b.) for compost biofilters with an optimum moisture content of 50% (w.b.). Microorganisms tolerate a range of temperatures. They are most active between 70 and 90º F [4]. Compost-based media have been used extensively in recent years because they are cheap and have diversified microbial communities capable of degrading various pollutants once they become acclimatized to the substrate. Therefore, the objective of this study is to investigate the relationships between Removal Efficiency and Moisture content, pH, Temperature. Methanol is used in this investigation as VOC, and a biofilter packed with compost and woodchips is employed.

MATERIALS AND METHODS

Experimental setup

The experimental set-up and its ancillary connections are shown schematically in Figure 1. The biofilter is made-up of acrylic column with the height and diameter of 110 cm and 5 cm respectively. The column has three sections. The first section is 10cm in height and that of second and third sections are 90 cm and 10 cm respectively. The first section is at the bottom; the second section is in middle and the third section is at the top. The filter bed material is kept at the middle section and its height is varied as 50, 65 and 80 cm respectively. A packing support is provided in between the sections 1 and 2. This is a perforated sheet made up of acrylic having the diameter of 0.4 cm. It is also used to distribute the vapor uniformly throughout the bed material. The methanol vapor is fed to the column at the bottom through rotameter. The initial vapor concentration is varied by mixing the vapor with air and fed to the rotameter in compressed form through the mixer. Before mixing with vapor the air is passed through the surge tank to become saturated. The gas sampling probes 1 and 2 provided at the sections 1 and 2 are used to collect the vapor samples. The initial and final concentrations of the vapor are analyzed using the gas chromatography equipment. The initial concentration of the vapor is varied from 0.6 to 3.2 ppm respectively. The bed temperature is noted by the thermocouple provided at the middle of the column (section 2). The composition of the nutrient solution is given in Table1. This nutrient solution is used to maintain the growth of micro organisms in the bed material. It also maintains the moisture content and the pH value of the bed material. The moisture content of the bed material is measured periodically by using moisture meter and maintained constantly. The pH is also monitored continuously using pH meter. Void volume of the packed bed is calculated by using the void volume and total volume.

Filter bed material
The filter media is a mixture of compost and woodchips. The proportion of compost to woodchips is varied at the ratios of 1:2, 1:1 and 2:1 by volume. A pH buffer solution is added periodically to the filter media to maintain the pH. Tables 2 represent the properties of the filter bed material.

Packing procedure and bed mixing
The columns are packed manually for each experimental run. The compost is taken approximately 600, 700 and 800 g wet basis for the compost to woodchips ratio of 1:2, 1:1 and 2:1 for the bed height of 80 cm. The weights of compost in compost woodchips mixture are 500, 600 and 700 g wet basis for the compost to woodchips ratio of 1:2, 1:1 and 2:1 for the bed height of 65 cm. Similarly the weights of compost in compost woodchips mixture are 400, 500 and 600 g wet basis for the compost to woodchips ratio of 1:2, 1:1 and 2:1 for the bed height of 50 cm. In all the sets experiments, the compost and woodchips are poured freely into the column until obtaining a height of 50, 65 and 80 cm respectively. Additional compaction of the media was avoided in order to allow only the natural compaction expected by the weight of the compost.

Temperature measurement
Gas temperatures before and after each column, bed temperatures, and ambient air temperatures were monitored with thermocouples and a temperature indicator system. Type-T (copper-constantant) thermocouples with welded and silicone coated ends were inserted into the centre of the reactor cylinders at locations previously displayed.

Moisture content
Approximately 10 grams of sample were placed in aluminium weighing dishes, and then into an 85°C oven for 24 hours. Weights of the samples before and after were compared to determine percent moisture content. Samples from the tested columns were taken from the external surface of the column cores at 0.05 m, 0.15 m, and 0.25 m along its length.

pH
The pH value for the compost was determined by mixing 20 ml of sample with 20 ml of distilled and deionised water in a 100 ml beaker and using a calibrated Beckman Φ200 pH meter to determine the pH of the solution. As with moisture analysis, samples from the biogas-exposed compost were taken from the external surface of the column along the length.

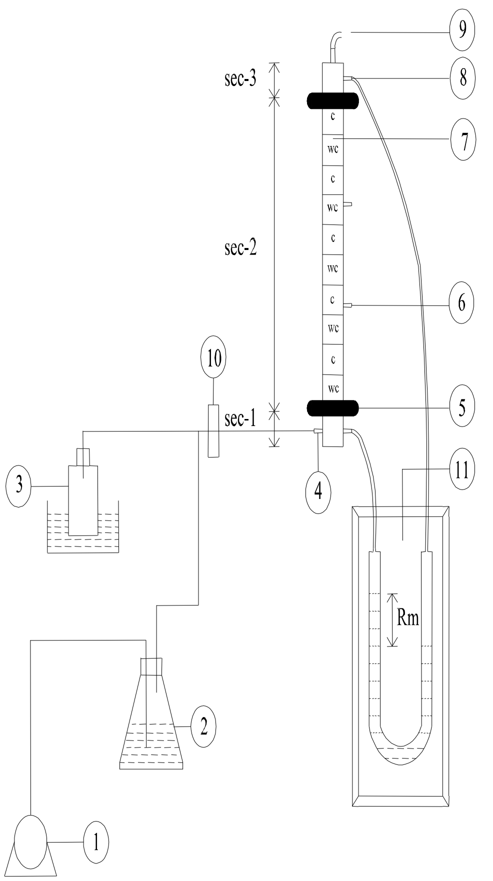

Fig 1: Experimental setup of biofilter
1 air compressor, **2** surge tank, **3** methanol vapor, **4** air-methanol vapor inlet, **5** packing support, **6** gas sampling probe-1, **7** bed material, **8** gas sampling probe-2, **9** vapor outlet, **10** rotameter, **11** Simple U tube manometer.

Table 1: Composition of one litre of the nutrient solution

Composition	Amount
KH_2PO_4	0.91 g
Na_2HPO_4 $12H_2O$	2.39 g
KNO_3	2.96 g
$(NH_4)_2$ SO_4	1.97 g
$NaHCO_3$	1.50 g
$FeSO_4$ $7H_2O$	0.20 mg
$MgSO_4$ $7H_2O$	2.00 mg
$MnSO_4$ H_2O	0.88 mg
Ma_2MoO_4 $2H_2O$	1.00 mg
$CaCl_2$	3.00 mg

Table 2: properties of filter bed material

Parameters	Values
Moisture	40 % -60 %
Temperature	28°c - 40ºc
pH	6 - 8
Average thickness of woodchips	3 mm
Porosity Compost to Woodchips ratio 2:1 1:1 1:2	 0.32 0.39 0.44

RESULTS AND DISCUSSION

Effect of Temperature, Moisture Content and pH on Removal Efficiency

Effect of Temperature on biofilter

Fig 1(a), (b) and (c) shows the effect of temperature on methanol removal efficiency. Removal efficiency is decreased with increasing bed temperature. This result that the removal efficiency was high 76.67% at 33°c and the removal efficiency decreased to 62.50% at 34.0°c for the bed height 50cm for the compost woodchip ratio1:2. These results are reliable with the literature. The same trend is reported by [10] that the Microbial activity was optimal at 22 to 35°C and [11] reported that the temperatures between 25°c and 35ºc have been suggested as suitable for biofilter performance, with 35ºc often noted as the optimum temperature for aerobic microorganisms.

However our study shows that the biofilter may be operated at a temperature of 34°c if the incoming methanol concentration is maintained at low level.In this study it is observed that the overall range lies between 30°c and 35ºc and it is found to be significant. [10] and [12] are reported that the bed temperature between 10°c and 40ºc are acceptable for mesophilic microorganisms most frequently present in a biofilter, but one should strive to keep the off-gas temperature close to their optimum range for biological activity 30°c - 35ºc.

Effect of Moisture Content on Biofilter

Biofilter media moisture control is essential for odour reduction through a biofilter. Inadequate moisture can allow the media to dry out, deactivating the microbes, and creating cracks and channelling of air which results in a reduction of filter efficiency. [9] and [10] are reported that maintaining an optimum moisture level is a key operational requirement for a biofilter. Moisture is necessary for the survival and metabolism of the Microorganisms.

Fig 2(a), (b) and (c) shows that the effect of moisture content on biofilter. The higher the moisture content for the bed material compost to woodchips ratio 1:2 is high; this is due to high water holding capacity of woodchip. But in the compost to woodchip ratio of 1:1 and 2:1 the moisture content is low, the reason may be due to the woodchip present in that ratio is low. These will cause the bed material to remove high pollutants and compactability may be reduced and pressure drop will be less. It is found that the overall moisture content range lies between 40% and 60%.[10,13] and[14] are reported that in general moisture content between 40% and 60% by wet weight is recommended to obtain optimum biodegradation. It is observed that the pressure drop is gradually increasing, this is because of moisture content is increased in the bed material due to chemical reaction occurs in the bed produces water. It is concluded that the increase in pressure drop in the biofilters is due to clogging as the result of increasing of moisture content on the packing materials. [9]and[15] are reported that the too much moisture can lead to compaction, clogging and the formation of anaerobic region. This study showed that moisture content could be maintained near the optimum value by the addition of the buffer solution used for pH control.

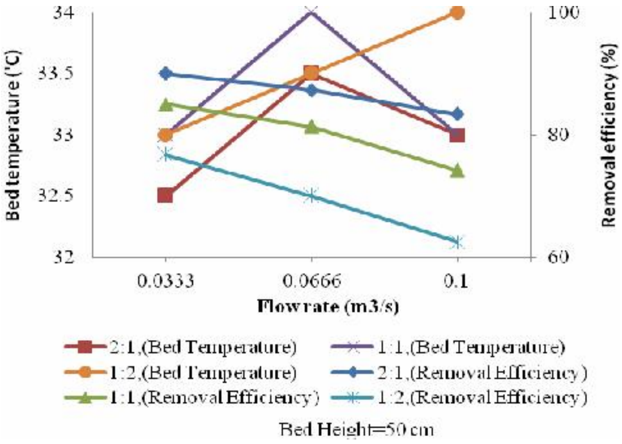

Fig 1 (a): Effect of Temperature on biofilter for the bed height of 50 cm

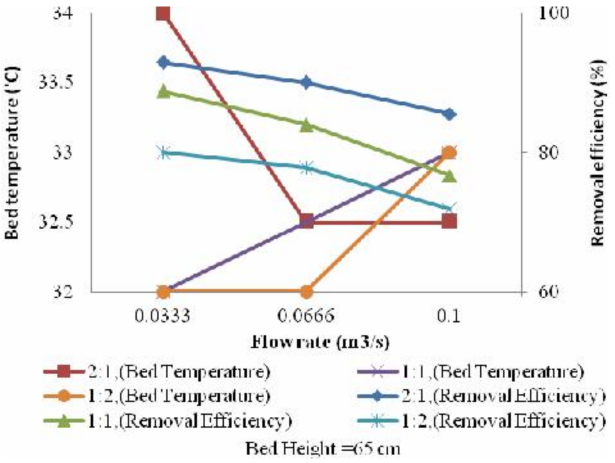

Fig 1 (b): Effect of Temperature on biofilter for the bed height of 65 cm

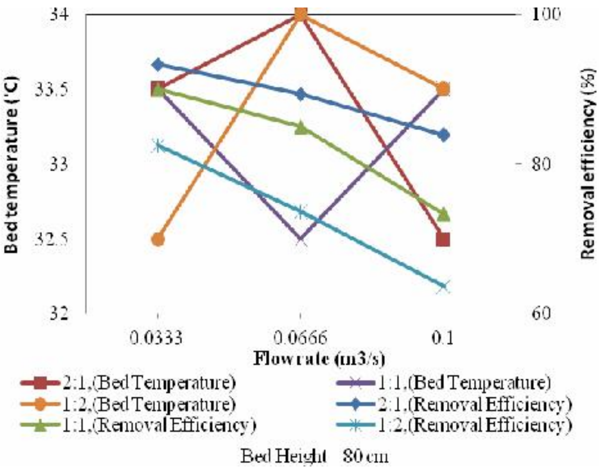

Fig 1(c): Effect of temperature on biofilter for the bed height of 80 cm

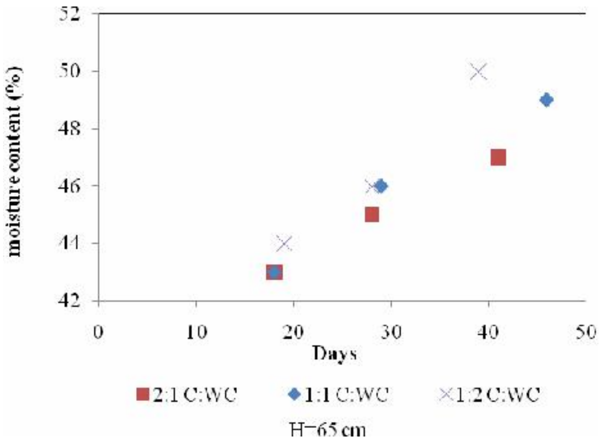

Fig 2 (a): Effect of Moisture content on Biofilter for the bed height of 50 cm

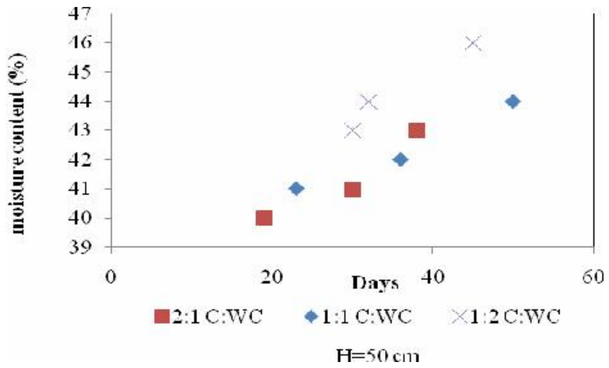

Fig 2 (b): Effect of Moisture content on Biofilter for the bed height of 65 cm

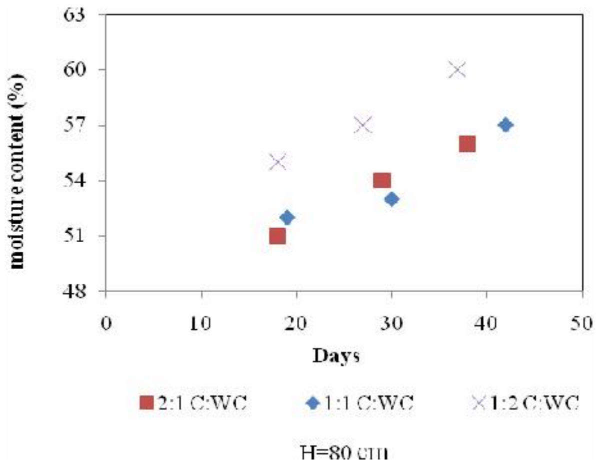

Fig 2 (c): Effect of Moisture content on Biofilter for the bed height of 80

Effect of pH on Biofilter

Production of acids over time will lower pH and will eventually destroy microbes. If a process emits pollutants that produce acids, a plan must be developed to neutralize these acids. There are several techniques available to neutralize beds. The nutrient solution may be added often to maintain pH in neutral over the top of the bed. Most bioreactors perform best when the bed pH is near 7, or neutral.[10, 12, 13] and [16] reported that the microorganisms capable of degrading VOCs optimum growth at pH values between 6 and 8. The same trend was found to occur in our study also that is the pH was monitored and measured, which is in the range of 6.5 – 8.5. [17] reported that pH decreased from its initial value of 7.1. The decrease was more pronounced at the bottom (pH 6.3 at spl) than at the top (pH 6.7 at sp4). The decrease was not sufficiently large to inhibit microbial activity.

The study shows that the pH was decreased from its initial value of 6.5. Some time it is increased to 8.5 at some locations. The decreasing trend was found at the bottom of the column, this may be due to introducing of high temperature gas at the bottom of the column. [18] and [19] are reported that the pH decrease can be explained by the production of organic acids from microbial activity. The increasing trend was found at the top of the column, this is due to the addition of nutrient solution in the top of the column to maintain moisture content at the optimum level.

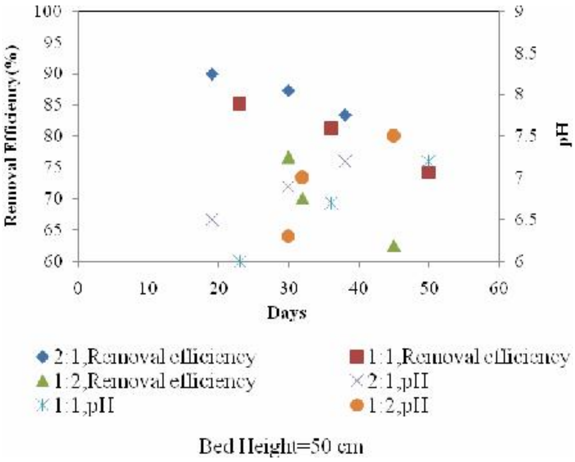

Fig 3(a): Effect of pH on Biofilter for the bed height of 50 cm

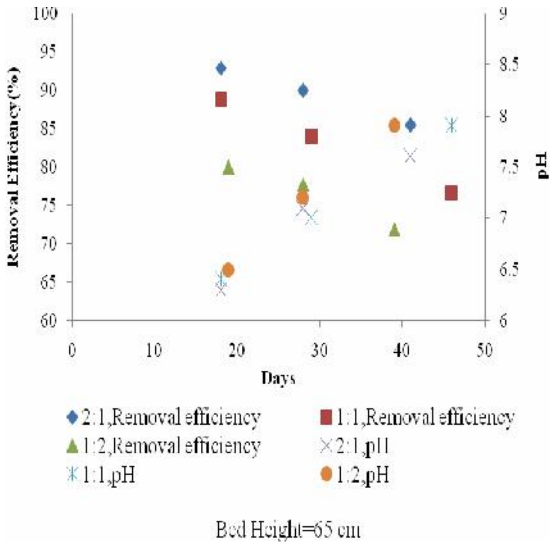

Fig 3(b) : Effect of pH on Biofilter for the bed height of 65cm

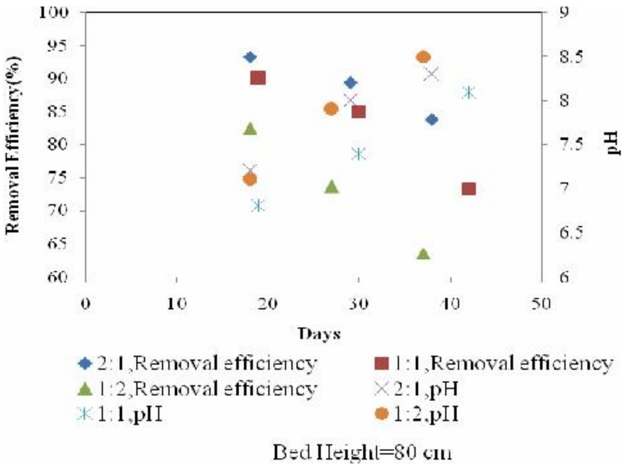

Fig 3 (c): Effect of pH on Biofilter for the bed height of 80 cm

CONCLUSIONS

The methanol gas stream was investigated in biofilters packed with compost-woodchip (2:1, 1:1, and 1:2) media. The result showed that the secondary parameters such as bed temperature, moisture content, pH were in the optimum level that is bed temperature in the range of 30°c and 35°c, moisture content overall range lies between 40% and 60% and pH was maintained in the optimum range between 6.5 and 8.5. The bed temperature, moisture content and pH all these parameters was found to be optimal for effective process and plays a vital role in reaching high values of removal efficiency.

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