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Wood Chip Based Filter Media For Removal Of Pollutants From Waste Air: Review

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Abstract: This study aimed to overview a biofilter packed with wood chips for the removal of waste air stream exhausted from the industries. Biofilter is an air pollution control technology that uses microorganisms to break down gaseous contaminants and produce harmless end products. They are efficient in reducing odour and control emissions from waste air streams. The majority of the biofilter media comprises various proportions of biological residues such as compost, peat, soil and bulking agents wood chips, heather, or synthetic material. This study reveals the overview of the woodchip based filter media removal of pollutants.
Keywords: Biofilter, Woodchip, Filter media, Removal efficiency, Air pollution.

INTRODUCTION

A huge quantity of VOCs is released from various industrial sources such as the petrochemical and printing industries, coating facilities, and hazardous waste sites. Biofiltration is a promising and attractive technology for the removal of volatile organic chemicals (VOCs) exhausted in the industrial waste air stream. Biofiltration uses microorganisms fixed to porous media to break down pollutants present in an airstream. The microorganisms grow in a biofilm on the surface of the media, or are suspended in the water phase surrounding the media. The filter-bed media consists of relatively inert substances (e.g., compost, wood chips, soil, peat), which ensure large surface attachment areas and additional nutrient supply. As the air passes through the bed, the contaminants in the air phases sorb into the biofilm, where they are biodegraded. Advantages of biofiltration include high removal efficiency, low cost, and low energy requirements[1]. Biofilter media selection is critical in biofilter design and performance. The bacteria and fungi living on the media oxidize volatile organic compounds (VOCs) and oxidizable inorganic gases and vapors[2]. The selection of packing materials is an important factor in maintaining high removal efficiency and a number of organic packing materials have been used successfully in Biofilters[3-6]. For a biofilter to operate efficiently, the media must provide a suitable environment for microbial growth and maintain a high porosity to allow air to flow easily. Critical properties of media material include (1)

porosity, (2) moisture holding capacity, (3) nutrient content, and (4) slow decomposition[7]. The objective of this study is to provide a brief overview of the current status of VOC biofiltration, with a focus on the woodchip as support media.

WOODCHIP AS PACKING MATERIAL

Woodchip have been extensively investigated as packing material for the removal of pollutants from waste air by different researchers. A summary of removal efficiency of woodchip based packing material for different types of air pollutants has been presented in **Table 1.**

Table 1: Removal efficiency of woodchip based packing material for the removal of different type of pollutants from waste air streams

S. No	Packing Material	Types of Pollutants	Removal Efficiency (%)	Years	Reference
1	Compost–woodchips	H_2S	99 %	2013	[8]
2	Flocor-R sheets, coffee husk blended with wooden chips	Wastewater	80 – 98%	2013	[9]
3	Woodchips , rice husk	Tri Ethyl Amine (TEA)	90 – 95 %	2012	[10]
4	Western cedar (WC) chips	Odour, H_2S, NH_3	51%, 83%, and 41%	2012	[11]
5	Woodchips	Hygroscopic load	-	2011	[12]
6	Compost, woodchips	Methanol &	93 %	2010	[13]
7	Wood chip	Various Pollutants	76% and as high as 93%	2008	[14]
8	Compost,woodchips	CO_2	-	2008	[15]
9	Woodchips	Growing-finishing pigs	60 %	2007	[16]
10	Leaf debris compost mixed with wood chips and activated carbon	Trichloro ethene	52% and 92%	2006	[17]
11	Compost and wood chips	H_2S	62 %	2005	[18]
12	Compost:woodchip, 30:70 to 50:50	Waste air stream	>90 %	2004	[7]
13	Municipal compost, wood chips	Toluene , xylene	94 ± 6% and 91 ± 8%	2003	[19]
14	Wood chips, granular activated carbon(GAC)	H_2S, NH_3	75-99% (H_2S) 30-92% (NH_3)	2002	[20]
15	wood chips and compost	Odour concentrations	56 to 94%	2002	[21]
16	Woodchips (Yard waste, Grocery waste, Poultry manure), Hemp hurds (Grocery waste), Straw (Grocery waste, Topsoil)	Odorous air and clean farm yard	26 to 51 OU	2001	[22]
17	Inert porous pellets (Nova Inert) and wood chips	Methanol	95%	2001	[23]
18	Compost , wood chip	Odour, H_2S, ammonia	42.3%, 69.1%,78.8% (Odour), 90%, 95% ,91% (H_2S) 6%,	2001	[2]

			49%, 81% (NH_3)		
19	Mushroom compost and wood chips	Odour, H_2S, ammonia	Approximately 90 – 95%	2000	[24]
20	Mushroom compost and wood chips	Mixtures of hydrophilic and hydrophobic volatile organic compounds	90 - 95%	2000	[25]

The rapid determination of complete elimination characteristics of target pollutants in waste air Biofilters was studied by Nicolai and Janni [2].The biofilter was filled with a mixture of mushroom compost and wood chips. The packing was buffered to near neutral with lime (25 kg m-3) and initially amended with slow release to prevent medium acidification and nutrient limitation, respectively. The void volume of the packing material was approximately 40- 50%. The same biofilter medium was used for a 3-month long study involving toluene and ethyl acetate vapor removal. During standard conditions, a mixture of toluene, methyl isobutyl ketone (MIBK), and isopentane was injected at a concentration of 0.2 g m^{-3} each. Under the test conditions, the pressure drop over the filter remained low (below 3 cm water gauge) for about a month and then slowly increased up to 11.2 cm water column as a result of packing compaction. Approximately 90 – 95% of removal efficiency was achieved.

Biofiltration of methanol [8] and Hydrogen sulfide vapor [13] from waste gas using compost and wood chips as filter bed material were studied by Premkumar and Krishnamohan. The biofilter used in this investigation is of 110 cm height and 5 cm in diameter. The inlet methanol vapor and H_2S concentration are varied from 0.6 to 3.3 ppm and 5 to 15 ppm. with the flow rates ranging from 0.033 m^3/s to 0.1 m^3/s. The equivalent empty bed residence time (EBRT) range is 9 to 30 s, 12 to 33 s and 15 to 48 s for the bed height of 50 cm, 65 cm and 80 cm respectively. The compost to wood chips ratios of 1:2, 1:1 and 2:1 are employed in this investigation. The effect of inlet air-methanol vapor flow rate and H_2S, inlet concentration, empty bed residence time, bed height and ratio of compost to wood chips on removal efficiency is studied and found to be significant. The maximum removal efficiency is found to be 93.33 percent. The biofilter removed as high as 596.06 g m^{-3} h^{-1} at the empty residence time of 38 s and the compost to wood chips ratio of 2:1.

The performance of aerated fixed film filters filled with Flocor-R sheets and coffee husk blended with wooden chips as a support medium for the treatment of wastewater under organic loading rate was fixed in the range of 0.8 Kg COD/m3d and HRT from 2-24 hours were evaluated by Vinod and Mahalingegowda [9]. Experiments were carried out to study the effect of organic loading rate, HRT on the removal of COD, NH3-N and phosphate. In this phase of operation two biological aerated filters(BAF's) filled with Flocor-R sheets and Coffee husk blended with wooden chips were continuously fed with Institutional hostel wastewater having an initial average COD of 800 mg/L, ammonia nitrogen of 4.32 mg/L and phosphate 24.6 mg/L. The biological filters was found to perform satisfactorily when operating under organic loading rate of 0.8 kg COD/ (m^3.d), in which the performance of COD removal was 96.4% and 88.4%, NH3-N removal of 81% and 78.2% for an HRT of 24 hrs was achieved. Phosphate removal was observed to be 98.2% and 90.7% in both the filters. Experimental work has shown that the filters were efficient for the treatment of organic wastewater of 0.8 kg COD/ (m^3.d) without backwash.

Gandu et al., **[10]** revealed that mixed bacterial strains named as AGR/IICT/1-5B was isolated from the active sludge of ETP of a polymerization industry. Strains AGR/IICT/1-5B was primarily identified as 3 gram positive and 2 gram negative bacteria. These strains were used for the abatement of TEA in bio filters. Experiments were conducted on biofilter having the working volume of 1.2 L. Microorganism was immobilized on mixture of wood chips and rice husk (1:1 v/v) which is used as the filter medium. The biofilter was operated at the following conditions; Temperature 30±1°C, pH values in the range of 7.0 -7.6, Loading rate at 1-144 g $m^{-3}h^{-1}$, EBRT at 20-40 s, moisture content at 50-59%. Removal efficiency in the range of 90-95% was obtained during the study.

A pilot-scale mobile biofilter was developed where two types of wood chips (western cedar and 2 in. hardwood) were examined to treat odour emissions from a deep-pit swine finishing facility in central Iowa by Chen and

Hoop [11]. The biofilters were operated continuously for 13 weeks at different air flow rates resulting in a variable empty bed residence time (EBRT) from 1.6 to 7.3 s. Results indicated that both types of chips achieved significant reductions in p-cresol, phenol, indole and skatole which represent some of the most odorous and odour-defining compounds known for swine facilities. The results also showed that maintaining proper moisture content is critical to the success of wood-chip based biofilters and that this factor is more important than media depth and residence time.

Ima and Mann [12] stated that increasing the moisture content of woodchips in a biofilter bin causes the material to expand, thereby imposing hygroscopic pressure on the bin wall. A swell test was conducted using a modified oedometer apparatus to determine the change in volume of bulk pine woodchips due to changes in moisture content.

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Lava rock, polyurethane foam cube (PUF), Pall ring, porous ceramic beads, porous ceramic Raschig rings and compost–woodchips mixtures were investigated by Kim and Deshusses [15]. The experiments were performed at gas velocities ranging from 100 to 8000mh−1 and liquid velocities of 0.1.12mh−1. The gas film mass transfer coefficient *(kGat)* of 50:50% vol compost–woodchips mixture, a common biofilter packing, was greater than this of a 20% vol compost and 80% woodchips mixture, though the mass transfer was not increased by increasing further the volume fraction of compost. All compost mixtures exhibited a greater gas film mass transfer coefficient than lava rock or other synthetic materials. The mass transfer coefficients of compost mixtures were also influenced by packing method and it was directly proportional to the surface area of the bulking agents added. The gas film mass transfer coefficient *(kGaw)* of five biotrickling filter packing materials increased linearly with gas velocity. The effect of liquid on the gas film mass transfer coefficient was not significant. Of all the biotrickling filter packings, the porous ceramic beads had the highest gas and liquid film mass transfer coefficients followed by lava rock, porous ceramic rings, 1 in Pall ring and PUF cubes. The liquid film mass transfer coefficient *(kLaw)* was directly proportional to liquid velocity and the effect of gas velocity was negligible.

The removal of odour and ammonia from outlet air using vertical biofilters in two units with growing- finishing pigs in the winter was investigated by Riis[16]. Woodchips were used as media in the wall of the biofilters. The measured odour removal efficiency averaged 60 %. In contrast, the biofilters did not reduce the ammonia concentration (ppm) significantly in the outlet air. The hedonic tone of the odour of the air was determined before and after the biofilter. The untreated air was recorded as more unpleasant than the air that had passed through the biofilters. In conclusion, the biofilters were capable of reducing the odour concentration in the outlet air from units with growing-finishing pigs in the winter. The biofilters treatment of the air made the odour less unpleasant. However, the biofilters were not capable of reducing the ammonia concentration in the outlet air in the winter.

A biofiltration system was developed by Tabernacka[17] et al., to remove TCE from contaminated air and to optimize its operating conditions. Three types of one- and two-step installations were examined for the capacity to remove gas-phase trichloroethene from waste air. The immobilizate of the biomass active in TCE decomposition was used in the process. The efficiency of the process and metabolic activity of biomass were investigated. The stable and effective biofiltration process was achieved when a two-step installation was used with hybrid bioreactor containing activated sludge suspension with active biomass immobilizate (bioscrubber) being the first step. The second step was a biofilter filled with traditional deciduous leaf debris compost mixed with wood chips and activated carbon. The efficiency of contaminant elimination achieved during 2.5 months of operation was between 52% and 92%. The bioscrubber activity in gas purification was high − even up to 76%, and biofilter capacity for contaminant elimination was in the range 65-88.3 g TCE/ m^3/h. Active strains of microorganisms selected in the course of the process were isolated and identified. Dominant bacteria belonged to the genus Streptomyces, Sarcina, Arthrobacter, Bacillus and also to Gramnegative rods from species Agrobacterium radiobacter and Sphingomonas paucimobilis. Moreover, two dominant strains of moulds and one strain of yeast were isolated from the biofilter-bed.

The performance of biofilter woodchip, rock wool and compost as medium for the removal of hydrogen sulphide was evaluated by Namkung [18] et al,. The biofilter packed with compost achieved more than 99% removal efficiencies, but shows higher pressure drop over the study period. In the case of woodchip biofilter achieved low removal efficiencies of 62% and minimal microbial accumulation were attained at a longer residence time of 80 sec. alternatively the rock wool bed provided high removal efficiencies greater than 96% with relatively low pressure drop.

David Schmidt[7] et al., examined that a proven organic media mixture for animal agriculture biofilters ranges from approximately 30:70 to 50:50 ratio by weight of compost and wood chips or wood shreds. The wood provides the porosity and structure while the compost provides microorganisms, nutrients, and moisture holding capacity. Media mixtures with more compost (less wood chips) will result in higher pressure drops but only slightly higher efficiencies.

The performance of two laboratory-scale biofilters filled with the same type of packing material were operated at different gas flow rates and influent concentrations of toluene and xylene in order to treat waste gas streams was investigated by Torkian[19] et al,. The columns contained a mixture of municipal compost as a base material and wood chips as a bulking agent in an 80:20 ratio; the porosity was 54%. During the start-up of the systems with inlet concentrations of 20 and 70ppm for toluene and xylene, respectively, high biomass growth resulted in pressure drops in excess of 2000 Pa m^{-1}. The results showed that organic loading rates of up to 110 and 150 g m^{-3} h^{-1} can be handled without any indication of the elimination capacity being saturated. Under these conditions, elimination capacities of 73 ± 4 and 73 ± 14 g m−3 h^{-1} and removal efficiencies of 94 ± 6% and 91 ± 8% were achieved for toluene and xylene, respectively.

The simultaneous removal of H_2S and NH_3 using two biofilters, one packed with wood chips and the other with granular activated carbon (GAC) was investigated by Kim[20] et al,. A mixture of activated sludge (as a source of nitrifying bacteria) and *Thiobacillus thioparus* (for sulfur oxidation) was sprayed on the packing materials and the drain solution of the biofilter was recirculated to increase the inoculation of microorganisms. Initially both of the filters showed high (99.9%) removal efficiency. However, due to the accumulation of elemental sulfur and ammonium sulfate on the packing materials removal efficiency decreased over time to 75 and 30% for H2S and NH3, respectively.

Mann[21] was investigated an open biofilters have previously been shown to reduce odour from typical swine production facilities, but it was not known whether the exhaust air contained sufficient heat to prevent the biofilter beds from freezing during ambient temperatures below -20LC without the use of insulation or supplemental heat. The biofilter media consisted of mixtures of wood chips and compost in ratios of 1:1 (BF1 and BF3) and 3:1 (BF2 and BF4) by mass. The wood chips originated as debris wood (i.e., pine, spruce, fir, cedar, aspen, birch, willow, and alder) on Cedar Lake in northern Manitoba. Four experimental biofilter units were retrofitted to a 2000-hog, 4-room feeder facility in southern Manitoba. Temperatures within the biofilter bed were constant at approximately 16LC when ambient temperatures ranged between +9.2 and –34.2LC during the period from September 1999 to February 2000.

The study on six different media mixtures in separate biofilter cells was carried out by DeBruyn[22] et al. Each biofilter cell had a 50% / 50% mixture (by mass) of a bulking agent and compost. The six mixtures were as follows YWW, GWW, PMW, GWH, GWS, TS. Among six mixtures three were based woodchips such as YWW, GWW, and PMW. The mean odour reduction for woodchip based packing material was 97%.

The effects of biomass accumulation and distribution on air pressure losses in biofilters were experimentally studied by Sagastume[23]. Two bench-scale biofilters, one packed with inert porous pellets (Nova Inert) and the other with wood chips, were operated under similar conditions with excess nutrients to treat an airstream containing methanol, at loading rates of 100–150 g methanol/m3 bed/h. The pressure drop varied nonlinearly with the amount of accumulated biomass and the amount of methanol consumed. Six fold higher pressure drops were measured in the wood chip biofilter than in the Nova Inert biofilter because of more biomass growth and bed compaction. The removal efficiency was achieved in the range of 95%.

Deshusses and Johnson[24] studied a biofilter media mixtures were compared in 18 pilot-scale biofilters treating pit gases from a swine facility. The compost and wood chips mixtures ranged from 100% wood chips to a 50–50 blend in 10% increments. The effect of three media moisture contents (low, medium, and high) on biofilter performance was also evaluated. Odour and hydrogen sulfide reduction did not change significantly for

mixtures with greater than 20% compost. For efficient odour, hydrogen sulfide, and ammonia reduction media moisture must be greater than 40% wb. Media moisture content influenced odor, hydrogen sulfide, and ammonia reduction more than the ratio of compost and wood chips.. As the amount of compost increased in the media mixtures, the pressure drop also increased. Based on this experiment, the recommended mixing ratio of compost to wood chips for biofilters on swine facilities is minimum 30% compost and 70% wood chips by weight.

The biofiltration was successfully applied to treat a mixture of (methanol) and (a-pinene) volatile organic compounds (VOCs) from contaminated air streams by Mohseni and Allen[25]. The experimental approach involved operating two identical bench-scale biofilters with media consisting of a mixture of compost and wood chips. The pure methanol with percentage removals of more than 90 - 95% and gas retention times between 20 and 60 s was achieved.

CONCLUSION

This review gives an idea about that the bio-filtration techniques can be employed effectively to treat pollutants such as volatile organic and inorganic compounds with the support of compost and woodchip. Many studies have been conducted using biofiltration techniques with different packing media. One of the paramount supporting media is compost and woodchip composition. It helps to reduce contaminations in the air streams as well as reduce chiefly pressure drop across the column and control the clogging of the bed over a period.

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