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Packing Material Evolutions and Odorous Abatement of Peat and Heather Biofilters Operating in Rendering Industry

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In this paper, the performances of three industrial biofilters treating rendering odorous emissions and the packing material evolution are presented and discussed. The biofilters were packed with a mixture of peat and heather, treating about 50 000 $m^3.h^{-1}$ of rendering gases which presented typical odorous concentrations ranging from 1 350 to 22 000 $OU.m^{-3}$ for ambient air from industrial facilities, and from 13 000 to 184 000 for processes gas (mixture of non-condensable and air from fat presses). During the two first months of running, the packing material has shown a rapid compaction of 30 to 40 cm, representing a 20 to 26.7 % reduction of the volume. pH of biofilters were compared to new material, showing a drastic acidification in the deeper part. The bacterial count on PCA medium showed that bacterial density depends on the packing pH, which also induces a selection of micro-organism species. The low colonization (inferior to $9.4x10^4$ $CFU.g^{-1}$) can be explained by the lack of inoculation at biofilter start-up, the lack of nutrients supply and by acidic pH.

1. Introduction

The rendering activity corresponds to the treatment of animal by-products according to sanitary standards rules. Among the environmental issues of rendering industry, odorous emissions are one of the major concern, which often cause nuisances to the surrounding plants population (Sindt and Engineer, 2006; Sironi et al., 2007, Smet and Langenhove, 1998). In fact, rendering odors are due to the interaction of multiple compounds such as: oxygenated hydrocarbons (aldehydes, carboxylic acids, ketones, esters), reduced sulfur compounds (H_2S, methanethiol), nitrogenous compounds (ammonia, amines, amides) (Defoer et al., 2002; Luo and Agnew, 2001). For example, Luo and Agnew (2001) have detected more than 300 compounds in process air from rendering plant. The odorous intensity of the air to be treated generally ranged from 10,000 $OU.m^{-3}$ for ambient air to 1,000,000 $OU.m^{-3}$ for cookers steams (Defoer et al., 2002; Luo and Agnew, 2001; Prokop and Bohn, 1985; Shareefdeen et al., 2002; Sironi et al., 2007). The effectiveness of preventive measures to limit odors formation is often limited, leading inevitably to the implementation of effective treatment methods. Conventional

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technologies include chemical scrubbing, combustion, thermal oxidation and biological technologies (Prokop and Bohn, 1985; Sindt and Engineer, 2006; Sironi et al., 2007; Smet and Langenhove, 1998). Among these, biofiltration have become popular thanks to its low investment and maintenance costs. Many successful applications were observed for the treatment of low concentrated gaseous emissions from water treatment plants, composting platforms and rendering plants (Devinny et al., 1999; Iranpour et al., 2005). Nevertheless, biofilters performances decline with time and become insufficient to limit olfactory nuisances. A biofilter consists of a porous organic bed, through which passes a humid polluted gas stream. A mixed culture of pollutant-degrading micro-organisms is immobilized at the material surface and carries on the conversion of VOCs (Volatile Organic Compounds) and odorous compounds into CO_2, H_2O, metabolites, energy and biomass (Deshusses, 1997; Devinny et al., 1999). Additionally to flow rate, composition and concentration of the influent, the performances of biofilters depend on many parameters such as: pH, humidity, nutrients concentrations and packing material structure (Deshusses, 1997; Devinny et al., 1999). In order to improve the performances of industrial biofilters operating in a rendering plant, a packing material and biofilter characterization was done.

2. Materials and methods

2.1 Rendering process and biofilters configuration

The rendering plant studied treats annually about 175,000 t of animal waste materials. After grinding, the raw materials are dehydrated in a continuous grease bath cooker, steam-heated at 140 °C. The resulting vapors are directed to an aero-condenser, which separate the condensates, directed to the water treatment plant, from the non-condensable fraction which is sent to the air treatment process (BF 2 and 3). The flours are degreased in a series of screw presses to reduce the residual fat content, where the vapors are sent to the deodorization process (BF 2 and 3). The atmosphere of the facility is collected and treated (BF 1). The rendering plant operated continuously, excepted during the week-end (no air stream passed through biofilters). The deodorizing unit is separated into three channels treating each 50,000 $m^3.h^{-1}$. Gas is washed in an acid scrubber (pH = 4), before entering in a biofilter, whose characteristics (EBRT: Empty bed Residence time) are presented in the Table 1. The three biofilters are similarly designed. A 70 cm plenum consisting of PVC duckboard supported a 25 cm stratum of wood chips. The biofilters were filled with 1 m of a mixture of peat and heather (30/70 v/v) and covered with 25 cm of fibrous peat. There were no inoculation at the biofilter start-up and no nutrients supply during the investigated period.

Table 1: Biofilters design

Biofilter	1	2	3
Depth (m)	1.5	1.5	1.5
Surface (m^2)	425	367	1050
Volume (m^3)	637	550	1575
EBRT (s)	46	40	113

2.2 Gases analyses

Olfactory analyses were done by external providers, according to the EN 13725 standard (CEN, 2003). The VOC content of the gas stream was measured, after collecting the gas sample in Nalophan bags, by a Graphite 52M-D analyzer (Environnement SA, France). H_2S and NH_3 concentrations were determined according to methods developed by Le Cloirec et al. (1988).

2.3 Packing material sampling and analysis

The packing material samples were taken after 48, 29 and 38 months of running for biofilters 1, 2 and 3 respectively, at three different depths on three different areas according to superficial gas velocity. They were collected with an electric core drill fitted with a modified bit (L: 400 mm, 102 mm), to collect the sample without structural alteration. The samples were stored in airtight containers. Microbiological analyses were performed within 2 h and physicochemical analysis within 24 h. Microbial extraction from the packing material was done using a protocol previously reported (Khammar et al., 2004). The suspension was then diluted from 10^1 to 10^5 with a sterilised solution of 0.9 % NaCl. A PCA (Difco™, pH: 7.0 ± 0.2) culture medium was inoculated with diluted suspensions to enumerate the total aerobic mesophilic flora. The number colony forming unit (CFU) was counted after 5 days incubation at 28 °C. Organic matter content (OM) and humidity were determined by standard procedures. The pH of the packing material was measured with a Cyberscan 510 pH-meter on leachates, after immerging and stirring (1 h, 750 rpm, 20°C) 4 g in 100 mL of ultra pure water.

3. Results and discussion

3.1 Olfactory impact of the effluent to be treated

The characteristics of the biofilters influent are shown in Table 2. The olfactory and physicochemical influent impacts differed depending on the nature of the stream to be treated. The mixture of process air and non-condensable fraction were the most odorant gases far ahead of the ambient air (BF 1). The wide range of odorous levels (7 analyzes campaigns between June 2007 and December 2011) indicates that the odorous emission of rendering industry is very variable and depends on the considered flow. A correlation attempt between the odorous loads and the plant operating conditions (steam flow, steam temperatures, seasonal effects) was unsuccessful due to the lack of operating data. Operating conditions such as opening doors period or type of materials processed remains inaccessible. Many authors emphasize the extreme variability of odorous emissions from rendering plants sites according to type of materials processed, state of freshness, season and kind of process (Luo and Lindsey, 2006; Rappert and Müller, 2005). In order to get a basis for sizing new odor treatment units, the data of the worst cases observed in Table 2 could be used.

Table 2: Biofilters influent characteristics

Biofilter	1	2	3
Origin of stream	AA	3 FP + 1 CNC	3 CNC + 1 FP
[H_2S] (mg.m^{-3})	0.1 – 4	1.6 – 17	2 – 9
[VOC] (mg C.m^{-3})	1.5 – 5	10 – 64	9 – 44
[Odors] (10^3 OU.m^{-3})	1 – 22	13 – 123	14 – 184

AA: Ambient air, FP: Fat presses, CNC: Non-condensable fraction from cookers air stream

3.2 Odor abatement

The odorous abatements as a function of biofilters running period are presented in Figure 1. The most significant changes made during the operating period are annotated on the graphs. The performances of the biofilter 1 remained stable during about 38 months with two reloadings of the packing materials with 20 cm of peat and heather mixture at months 11 and 27. The low applied loads (< $2x10^5$ OU.h^{-1}.m^{-3}) were well treated, with more than 90 % in all cases. Nevertheless, the load increase observed at the 41th month induced a decrease of performance, and the packing reloading with 20 cm of peat and heather (47th month) improves the elimination rate from 72 to 95 %. The performances of the biofilter 2 were acceptable during the first 20 months of running with odor removal efficiency upper than 85 %, for applied loads ranging from 1.1 to $2.8x10^6$ OU.h^{-1}.m^{-3}. Nevertheless, a performance decrease was observed at the 23th month, despite no variation of the odorous loads. This performance decrease led to the implementation of a new peat and heather packing, which presented poor performances at the biofilter start-up with only 51 % of odor elimination after 2 weeks of run. After 4 months of run the odor elimination remained under 80 % and decreased to 65 % at the 12th month even though an applied odorous load decrease from 12.6 to $3.5x10^6$ OU.h^{-1}.m^{-3}. The performances of biofilter 3 remained suitable during 32 months for the treatment of applied loads lower than $4x10^6$ OU.m^{-3}.h^{-1}. The implementation of new material never allowed performances better than 62 % after 6 months of running for the treatment of moderate loads (from 1 to $5x10^6$ OU.m^{-3}.h^{-1}). To conclude, the treatment of rendering emissions by peat and heather biofilters in these conditions (No inoculation, no nutrient supply and no addition of pH buffer) seems to be effective for odorous inlet loads lower than $4x10^6$ OU.m^{-3}.h^{-1} during a maximum running period of 38 months, including one or two packing reloading, as observed on the biofilters 1 and 3. The performance decrease reached much faster on a biofilter treating larger loads. The performances of biofilters never exceeded 85 % for loads from 4.1 to $12.7x10^6$ OU.h^{-1}.m^{-3}, and decreased rapidly after only 12 months of run despite one packing reloading.

The poor performances reported at the start-up underline the needs of inoculation which could maybe done by an acclimated inoculum, as suggested by Barona et al. (2008) to shorten the start-up time.

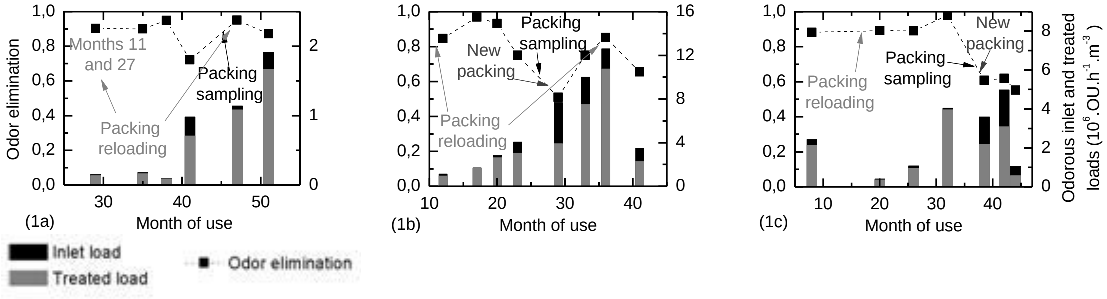

Figure 1: Performances of biofilters: a) 1,b) 2 and c) 3

3.3 Packing material compaction

The three packing materials compacted from 30 to 40 cm during the first two months of run which representing a 20 to 26.7 % volume reduction, leading to void space and gas residence time decrease.

3.4 Humidity of the packing material

The humidity of the packing samples revealed heterogeneous values for biofilters 1 and 3 (Figures 2a and 2c). The results underlined a moisture gradient in biofilter 3, which decreased with the depth. This phenomenon is typical of up flow gas and the down flow water column and could be explained by the packing drying by the unsaturated air stream in the deeper part and by the saturation of superficial peat by watering. This result highlighted current watering system deficiencies. There was no correlation between superficial air velocity and humidity gradient, maybe due to the difference between local measurement of moisture and overall measurement of surface velocity performed on a 1 m^2 area.

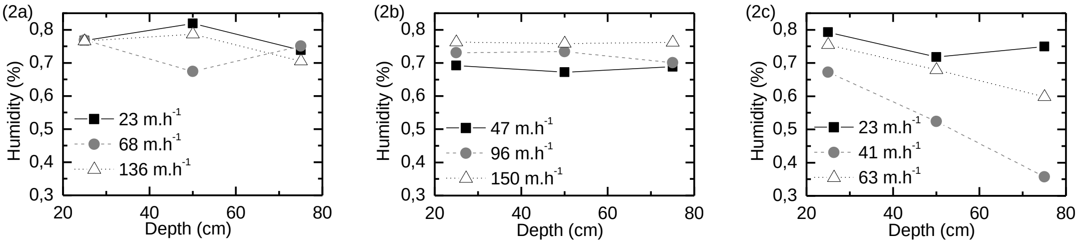

Figure 2: Humidity of biofilters :a) 1,b) 2 and c) 3 as a function of depth

3.5 Organic matter content

According to high pollutants loads observed, the biofilter 2 presented the highest degree of mineralization (73.1 %) comparing to biofilters 1 (76.6 %), biofilter 3 (95.0 %) and new material (99.0 %). These results could be linked to the high loads treated by this biofilter comparing to the others. The high degree of mineralization of biofilter 1 may be due to the extensive period of run (47 months).

3.6 pH measurements

The biofilter 1 is the less acidic (3 < pH < 7) contrary to biofilters 2 and 3 which shown pH comprised between 1.7 and 3 (Figures 3a, 3b and 3c). It could be explained by the most important sulfured compounds loads applied to these biofilter which induced a greater accumulation of sulfuric acids in the deepest fraction. There is a pH gradient along the biofilter 1 bed height and on the highest superficial velocity area of the biofilter 2 (150 m.h^{-1}). For the other cases, acidification was so pronounced over the entire bed height that no pH gradient could be observed.

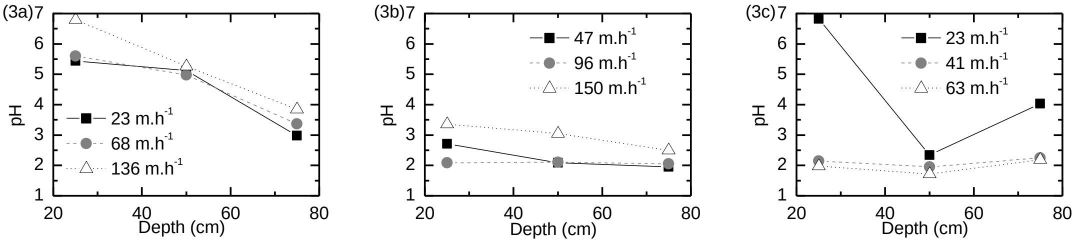

Figure 3: pH of biofilters: a)1,b) 2, and c) 3 as function of the depth

3.7 Microbial enumeration on PCA medium

In most cases, the packing material colonization shown in Figure 4 presented the same evolution than the pH along the bed height observed in Figure 3. Indeed, the biofilters colonization ranged from 1.2×10^{1} to 9.4×10^{4} CFU.g^{-1}, depending on the pH according to Figure 5. These values were lower than those reported by Shareefdeen et al. (2002) on soil biofilter treating rendering emissions (1.7 to 4.4×10^{6} CFU.g^{-1}), probably because the pH samples remained between 4.9 and 7.0.

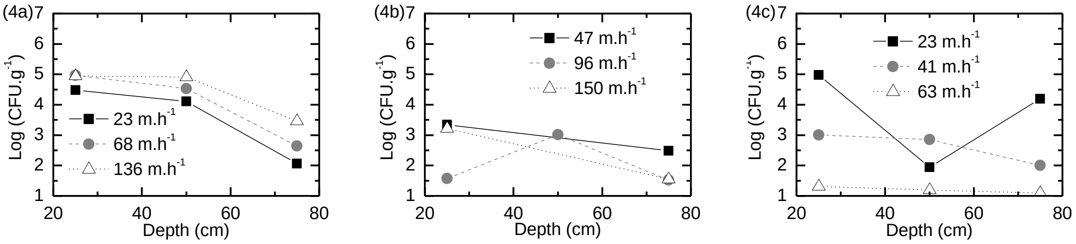

Figure 4: Colonization of biofilters: a)1,b) 2 and c) 3 as a function of depth

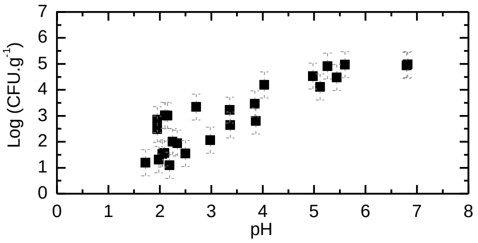

Figure 5: Colonization as a function of pH

According to Figure 5 which present the biofilter 1 PCA culture of samples taken from the area with the highest superficial velocity (136 m.h^{-1}), the microbial population which grew on the PCA medium differed as a function of the bed height, and some red bacteria appeared in deeper acidic parts.

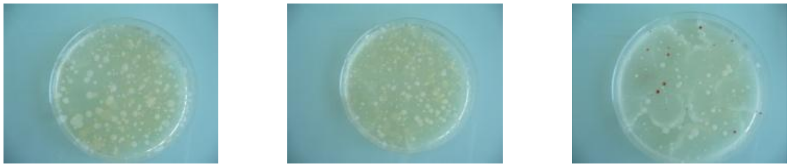
1a: 25 cm-pH:6.8
1b: 50 cm-pH:5.3
1c: 75 cm-pH:3.8

Figure 5: Evolution of the colonization of biofilter 1 as a function of the bed height

4. Conclusions

In conclusion, peat and heather biofilters underwent several structural and physico-chemical changes during their use, which can explain the loss of performances observed after few months of work. A settlement was observed in less than two months on each biofilter. The packing material moisture remained heterogeneous for extensive covered biofilter (1,050 m²), both on the surface and in depth. A humidity gradient was observed which reflect the drying of the deepest part by the unsaturated air stream and the saturation of the upper part by the superficial watering.

The degradation of high load odorous components induced the production of acid metabolites which contributed to an exacerbated acidification of the bed (pH values from 1.7 to 3.5). This phenomenon was less pronounced for biofilters treating low concentrations (pH values between 3 and 7). These acidic pH values explained the low colonization of bacteria which remained below 1.0×10^3 CFU.g^{-1} for acid samples (pH < 2.5) and upper than 1.6×10^4 CFU.g^{-1} for pH values superior to 5. Moreover these extreme pH values induced a microbial selection across the bed height.

To optimize the biofilters performances, some simple actions should be done. Inoculation at the biofilters start-up, nutrients supply and acid buffering incorporation should give a conducive environment for the development of an efficient microbial consortium. The optimization of the watering system should lead to the best management of the humidity. Finally, the selection of a more structured material would reduce the compaction, allowing to optimize the available biofilter volume. The influence of these parameters will be tested in future studies.

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