CHEMICAL ENGINEERING TRANSACTIONS Volume 17, 2009
Editor Sauro Pierucci
Copyright © 2009, AIDIC Servizi S.r.l., ISBN 978-88-95608-01-3 ISSN 1974-9791
DOI: 10.3303/CET0917061

Performance comparison between peat and wood chips as biofiltrating media in NH_3 abatement

Selena Sironi[1], Larua Capelli[1], Paolo Caruson[2], Alessio Cammerieri[1]
1 - Politecnico di Milano, Laboratorio Olfattometrico, Dipartimento CMIC "Giulio Natta", Piazza Leonardo da Vinci 32, 20133 Milan, Italy.
2 – Air Clean S.r.l. Via Trento, 37 Rho (Mi)

The comparison of removal performance between two biofilter packed with peat and wood chips were carried out at different operational parameters, such as air inlet temperature and ammonia inlet load. Moreover, operational conditions relevant to different biofiltration phase (acclimatization, water and ammonia supply interruption) were monitored. Peat resulted in better ammonia removal efficiency and stability of the system; peat critical load is 21 g Nm^{-3} h^{-1} and peat packed biofilter shows constant performance under variable operational conditions. Nonetheless peat is prone to lose its physical and mechanical features in consequence of lack of irrigation.

1. Introduction

Biofilter and biotrickling filter have been recently considered as one of the best available technologies for waste gas treatment and odor removal. The process involves biological oxidation: polluted air is supplied through a filtrating mean and pollutants are removed by transfer to liquid film (biofilm) on a solid support; then bacteria use contaminants as nutritional source by oxidizing contaminants to carbon dioxide, water and biomaterial. The main odorous compounds released from several industrial processes are ammonia and hydrogen sulfide (Devinny at al 1999a).
This research focuses on the design and set up of a pilot-scale biological filter that allows to compare the odor removal performance of two different packing materials. The systems offers the possibility to compare a cheap commonly used packing material with a filtrating mean supposed to have optimal performance on the basis of his chemical-physical properties and allows to decrease managing costs. During the experimental phase, operational conditions were varied in order to evaluate the filter response. Parameters such as pH, outlet air temperature, humidity and contaminant concentration were monitored in order to asses the filter performance.

2. Materials and methods

2.1 Experimental design

The experimental facility consists in two vertical units placed in parallel on the same bench: each unit consists in a PVC, transparent and cylindrical tube having a length of 1

Please cite this article as: Sironi S., Capelli L., Caruson P. and Cammerieri A., (2009), Performance comparison between peat and wood chips as biofiltrating media in nh3 abatement, Chemical Engineering Transactions, 17, 361-366 DOI: 10.3303/CET0917061

m, 20 cm diameter and 3 mm thickness. Both extremities consist of a PVC, 8 mm thick seal with a central hole. The upper one is used to supply odorous contaminants and water, in order to humidify the packing materials and the air streams; indeed it was considered more effective to realize air humidification directly across the filter. This way dry air strips nearly all the water introduced at the top of the filter in the first layer (centimeters), promoted by dispersion the packing material particles. The bottom one is used to collect leachate. Though industrial biofilters are normally operated in upflow mode in order to release the air directly in the atmosphere, the experimental facility was operated in downflow mode. Indeed, since the drying process begins at the inlet side, operating the biofilter in the downflow mode can facilitate moisture addiction to the bed (Dragt and Van Ham, 1992). Packing material was manually loaded and lightly packed until the desired height (85 cm). Bioreactor is fed with a hot air stream coming from the outside line. A diluted ammonia solution is fed at the top of each bioreactor to achieve both air and medium humidification and providing contaminants to the microorganisms growth. Every liquid stream is trickled directly on the bed using a peristaltic pump Gilson TM Minipulse Evolution III.

2.2 Analyses

Headlosses across the biofilter were measured using a differential pressure manometer. Pressure drop measurements were taken at the air sampling port at both the inlet and the outlet of the biofilter column. The measurements were taken at the start and at the end of the experiment.

pH of leachate was measured either by a pH-.meter or using pH test strips. Both the inlet and the outlet air stream temperature were measured with a thermometer.

The moisture content of the packing material was measured drying a weighted sample of filtrating mean withdrawn from the filter in an oven at 120 °C for 24 hours. The outlet air humidity is controlled using a datalogging humidity-temperature meter of RS ranging between 0 and 90 % (Accuracy of ± 0.1 %).

The outlet NH3 concentration was measured using an analyzer with an integrated recorder Drager CMS (Chip Measurement System) in a range from 0 to 50 ppm. The inlet concentration was given, since it was chosen to feed a solution of commercial ammonia and tap water with fixed concentration.

2.3 Packing material

This work aimed to compare the performance of two packing materials. It was chosen to compare a cheap ad commonly used filtrating media such as wood chips with a packing material considered more efficient according to its physical and chemical properties. Peat has a higher micro-porosity (40 %) and particle density (600 Kg/m3) compared to those relevant to wood chips, 1 – 5 % and 200 Kg/m3, respectively. The higher peat density leads to a three times more weight of material per volume of biofilter (11.7 Kg for peat and 4.3 Kg for wood chips); this difference is due also to the more regular and spherical peat particle shape and smaller particle diameter (0.015 m for peat and 0.005 m for wood chips. Peat pH value is 5.2 whereas the wood chips value is around 6.4.

2.4 Media preparation and acclimatization

Microorganisms were added to the medium by addiction of a solution of yeasts (300 g), and water (8 l) at the temperature of 30 °C to accelerate the acclimatization process.

Leachate collected at the bottom of the biofilter was recycled manually to the top for three times. The freeze dried bacterial culture provided by Bord na Mona®, is a mixture of up to 21 microbial species including *Rhodococcus*, *Bacillus*, *Pseudomonas* and *Trichoderma* species. The total viable count is approximately 10^9 cfu/ml.
The operational parameters of the biofilter during the acclimatization period were maintained at a temperature of 35 °C, an irrigation rate of 0.5 ml/min , an airflow rate of 17.3 l/min, an empty residence time (ERT) of 90 sec and tan outlet air humidity of 90%. Since microorganisms could be blown out the filter detaching from the packing material, a low air flow rate value, involving a high ERT, was selected in order to create optimal condition to enhance bacteria activity during the acclimatization period. The temperature was maintained in a range of 20 – 40 °C (M. Mohesini, 2000), which is considered to be optimal for the microorganisms life.

3. Results

3.1 Evaluation of breakthrough load

The first aim was the assessment of the media breakthrough point. This task was accomplished by placing a specific amount of packing material inside a 250 ml becker in order to reproduce the condition within packed biofilters. Then the medium was sunk in 50 ml of ammonia solution (5 %) and the system was stirred manually every 3 hours for 2 days with the purpose to reach the equilibrium, state between solid and liquid phase. The volume of ammonia adsorbed on material is computed measuring the pH of the liquid phase inside the becker and comparing it with the pH of the ammonia solution (pH = 12.03).

Table 1 – Weight of sampled, pH of liquid inside the becker, volume of adsorbed ammonia in case of peat.

Nr. Samples	Weight (g)	pH_{eq}	V_{ads} NH_3 (ml)
1	9	11.2	97235
2	20	11.1	35859
3	35	10.6	28322
4	41	11.1	22163

Table 2 – Weight of sampled, pH of liquid inside the becker, volume of adsorbed ammonia in case of wood chips.

Nr. Samples	Weight (g)	pH_{eq}	V_{ads} NH_3 (ml)
1	11	10.95	30092
2	27	11.18	11916
3	37	10.2	10023

The results show that increasing the weight of sampled came in decrease in the volume of adsorbed ammonia, reaching an asymptotic value. This behavior can be explained considering that the conditions inside the becker are more similar to those characteristic of a packed biofilter. Volume of adsorbed ammonia per volume of biofilter and mass of material are 200 g/$V_{biofilter}$ and 17.1 g/Kg for peat and 85.5 g/$V_{biofilter}$ and 20.5 g/Kg for wood chips, respectively.

The previous results show that peat and wood chips have nearly the same adsorption capacity, but the ammonia adsorbed per volume of biofilter is two times higher for peat with respect to wood chips. This difference is due to the different density of two materials.

On an industrial level, the volume of packing material is more significant than the weight of the medium; the filtrating facility has a larger superficial area ($\approx 550\ m^2$) and relatively low height (1 m), thus the space occupied by the biofilter has a remarkable importance in the industrial plant. Since peat need half medium volume les than wood chips in order to achieve the same adsorption efficiency, this leads to a better managing of the space of the factory and better removal performance.

3.2 Evaluation of mechanical features of peat and wood chips under specific operational condition

The following experiment aimed to evaluate mechanical features of peat and wood chips under severe operational conditions such as insufficient irrigation and dry air flow rate. Unlike wood chips, peat has a microporous structure, thus humidity of material contributes to swell the pores giving more superficial area for biofilm development. Lack of water can lead to a collapse of this structure, loss of volume, loss of specific surface area and thus loss of removal efficiency. The experiment was performed by flowing a dry, hot air stream through two biofilters packed with peat and wood chips respectively. After 20 days, both packing materials were withdrawn and weighted (**Table 4**).

Table 3 – Parameters and results of the experiment.

PARAMETER	PEAT	WOOD CHIPS
Initial H of the bed (cm)	85	85
Final H of the bed (cm)	65	83
Initial weight (Kg)	11.6	5.8
Final weight (Kg)	8.2	4.6
Loss of volume (%)	23	2
Humidity (%)	45	21

3.3 Evaluation and comparison of performance of two biofilters packed with peat and wood chips with a specific inoculums.

3.3.1. Acclimatization period

The acclimatization period for wood chips packed biofilter lasts approximately 9 days long, a slightly shorter period compared to the acclimatization period in case of not inoculated, fresh material. Peat packed biofilter is much faster in adapting to new conditions and the acclimatization period turned out to be less than one day.

3.3.2. Increasing ammonia inlet concentration

The following figure shows the ammonia removal efficiency trends in function of the contaminant load.

a) b)

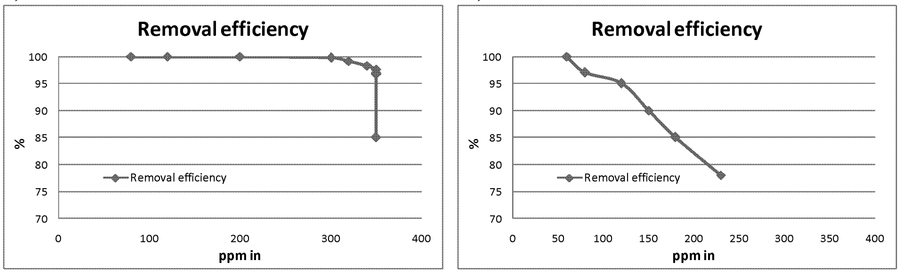

Figure 1 – Trend of removal efficiency of an inoculated biofilter packed with peat (a) and wood chips (b), respectively.

The critical load is the maximum ammonia inlet load corresponding to the decrease of removal efficiency value relevant to the steady–state operating conditions. This paramet4er is important for the scale-up of the biofilter, because it allows to avoid the dependence of the removal efficiency on volume of biofilter and inlet gas flow rate. Critical load for a wood chips packed biofilter is 120 ppm whereas the value for a peat packed biofilter is 300 ppm.

3.3.3. Response of biofilters to water and ammonia interruption

Concerning industrial field, periodically scheduled interruptions of the process lead to the necessity of quick response of biofilters to the process resumption. The figure shows the removal efficiency of both biofilters after a 16 days interruption of water and ammonia supply.

a) b)

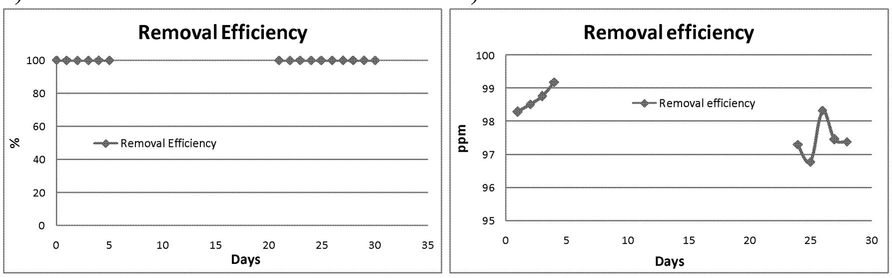

Figure 2 – Trend of removal efficiency of an inoculated biofilter packed with peat (a) and wood chips (b), respectively.

The removal efficiency remained constant even after interruption; moreover, the humidity of the outlet gas flow remained around 80 % slightly lower than before the interruption.

3.3.4. Evaluation of the influence of the inlet gas stream temperature on removal efficiency

The experiment demonstrates a strict dependence of the removal capacity on temperature, due to the sensitivity of microorganisms to the life conditions. It resulted that the optimum temperature correspondent to the highest removal capacity is around 35°C.

3.4 Evaluation of headlosses across the filtrating bed

An important parameter to take into account is the headlosses. The higher the pressure drops, the higher the compaction of filtrating bed and thus the higher the pump prevalence in order to supply the air stream across filtrating bed, giving lower removal efficiency as result. Pressure drops depend on air flow rate and especially working time of the packing material.

The headlosses were measured after a 3 months period, which represents about 15 % of the working life of a common organic packing material on industrial level. Even though the pressure drops did not increase considerably in both cases after the experimentation, the peat resulted to offer less resistance to the passage of the air stream compared to the pressure drops relevant to the wood chips bed. This is due to the different material structure.

4. Conclusion

The results of the previously described experiments lead to the following conclusions:

- Peat adsorbed 210 ml of ammonia whereas wood chips adsorbed 91 ml of the considered contaminant in the same volume of material (around 26 l).
- Peat has a microporous structure granting higher removal efficiency than wood chips; this feature makes peat sensitive to insufficient irrigation.
- Inoculated filtrating bed has higher removal efficiency and a faster acclimatization period than not inoculated wood chips bed.
- The critical load for the ammonia is 21 g Nm-3 h-1 and 16 g Nm-3 h-1 for peat and wood chips packed biofilter, respectively.
- Both biofilters show a quick response to fluctuating loads and a good humidity buffer capacity
- The optimal gas stream temperature is around 35 °C.

References

Dragt, A.J., Ham, J., 1992, Biotechniques for air pollution abatement and odour control policies. Proceedings of an International Symposium. Elsevier Science Publishers, Maasticht, The Netherlands.

M. Mohseni, D. G. Allen, 2000, Biofiltration of mixtures of hydrophilic and hydrophobic volatile organic compounds. Chemical Engineering Science. Vol. 55, 1545-1558.

H. Duan, L. C.C. Koe, R. Yan, X. Chen., 2006, Biological treatment of H2S using pellet activated carbon as a carrier of microorganisms in a biofilter. Water Research. Vol. 40, 2629-2636.

J. S. Devinny, M. T. Afzal, D. M. Mainville, 2004, Biofiltration of odorous: laboratory studies using butyric acid. Advances in Enviromental Research. Vol. 8, 397-409.