Microbiological and operational monitoring for the removal of H_2S and NH_3 under transient conditions by a biofiltration system using compost as packing material

D.G. Vela-Aparicio [1], D.F. Forero [2], C.A. Fisco[2], M.F. Paternina [2], C. Roman [2], P.F.B. Brandão[1]
I.O. Cabeza[2]

[1] Department of Chemistry, Universidad Nacional de Colombia, Bogotá D.C., Colombia
[2] Department of Environmental Engineering, Universidad Santo Tomás, Bogotá D.C., Colombia
Keywords: Biofiltration, compost bed, H_2S, NH_3, Microbial community.
Presenting author email: dgvelaa@unal.edu.co

The treatment of wastewater produces offensive odors that could affect people's health and their quality of life due to the proximity of the plants to cities or residential areas. These odors are caused by a mixture of volatile compounds, such as hydrogen sulfide (H_2S) and ammonia (NH_3), which are associated with anaerobic degradation of organic matter (Lewkowska et al. 2016). Biofiltration offers a low investment alternative for the removal of these pollutants with low waste generation and high efficiency. A common situation in industrial emissions is the presence of gas mixtures, changes in the concentration of the compounds and, in the case of biofiltration, changes in bed moisture. These conditions generally decrease the elimination efficiency for one or more compounds, mainly due to inhibition of microbial activity(Iranpour et al. 2005). In this work, the microbial community present in two biofilters, packed with composted chicken manure-sugarcane bagasse (BA), was monitored during the simultaneous removal of H_2S and NH_3 under transitory conditions of gas load and bed moisture to establish optimal operative conditions.

Materials and Methods

The pilot system consisted in two biofilters, constructed in PVC pipes of 10.16cm of diameter, 0.81 m of height and total volume of 0.007m^3(6.57 L). H_2S and NH_3 was produced by volatilization from acidic solution of Na_2S and NH_4OH 1%, respectively. An air compressor and two vacuum pumps were used to apply the ascending gaseous stream through the biofilters. The beds were compost from chicken manure mixed with sugarcane bagasse with a particle size higher than 2 mm in a 1:1 volume ratio (Vela-Aparicio et al. 2019).

The work was divided in two phases. Initially (Phase 1), the effect of load gas was evaluated by changing the residence time in the bed (EBRT). Different EBRT (60, 33, 25 and 18s) were evaluated for two levels of concentrations of H_2S (50 and 250 ppm) and NH_3 (4 and 19 ppm), each level had an approximate duration of four days.

The EBRT with the highest elimination capacity was selected to evaluate the effect of moisture content on the biofilters performance (Phase 2). The moisture content evaluated was 40%, 30%, 25% and finally decreases to 20%. The evaluation was made at a constant concentration of gases: 70 ppm H_2S and 5 ppm NH_3, which correspond to loads between 10-11 g/m^3 of H_2S and 0.5-0.6 g/m^3 of NH_3.The input and outlet gas concentrations were measured three times per day with gas detectors (MultiRAE Lite and BIOGAS 5000-Landtec when H_2S concentration was higher than 100 ppm). The microbiological monitoring was carried out by colony count (CFU/g) in selective agar media for ammonium- (AOB), nitrite- (NOB) and sulfur- (SOB) oxidizing bacteria for compost samples taken from the bed before changing the EBRT and moisture content (Kim and Ivanov 2000; Kim et al. 2002).

Results and discussion

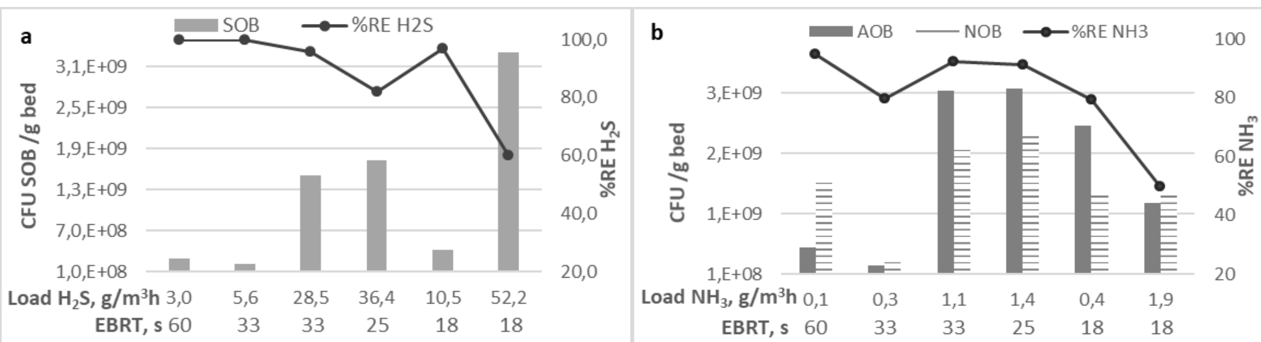

Figure 1. Microbial evaluation of biofiltration bed under transitory conditions of gas load a. Removal of H_2S by sulfur oxidizing bacteria (SOB); b. Removal of NH_3 by ammonium- (AOB) and nitrite- (NOB) oxidizing bacteria

Figure 1 shows an increase in bacterial counts as the gas load rise, finding the highest abundance of bacteria when the gas load was high at EBRT of 33 and 25 s. During this time, the gas removal efficiency was higher than 80%. However, as the EBRT decreased to 18 s, the removal efficiency and the abundance of AOB and NOB decreased dramatically (Fig 1b). In the case of SOB, although its abundance increased considerably, the decrease of efficiency at high gas load indicates that the microbial community is possibly under stress and cannot oxidize the gases. The decrease in the ER as

the EBRT is reduced has been reported previously in biofiltration and is due to the reduction in the mass transfer of the pollutants in the gas phase to the liquid phase (Ben Jaber et al. 2016).
The maximum elimination capacity of both gases was reached at the higher level of concentration and EBRT of 25s (30 g H_2S /m^3·h and 1.4 g NH_3 /m^3·h). These results suggest that at EBRT of 25s, the performance of biofilter at operational and microbial levels was optimum, therefore this time was selected to evaluate the effect of moisture content in the biofiltration of H_2S and NH_3.

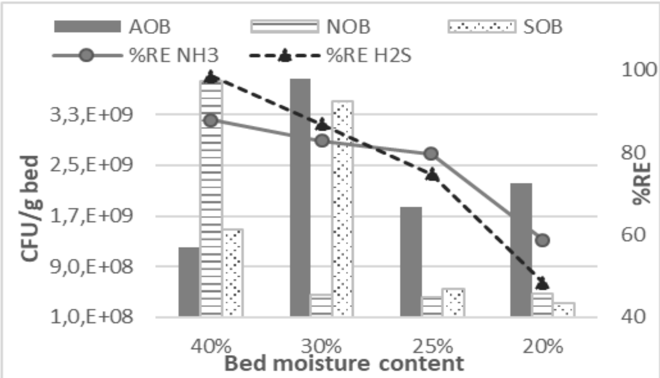

Figure 2. Microbial evaluation of biofiltration bed under transitory conditions of moisture content on the bed.

The reduction in moisture caused a decrease in gas elimination and mainly affected NOBs, whose abundance decreased 10 times (Fig 2). On the other hand, AOB and SOB increased their abundance at 30% but decreased when the moisture diminished. This is due to the decrease in the water content in the surface of the compost particles affects the adsorption and transfer of the gases to the biofilm, as well as the microbial activity(Rene et al. 2013). These results showed that the high removal efficiency is reached at 40% of moisture content, where the physicochemical and microbial processes occur more easily due to the high availability of water. Nonetheless, the bacterial groups related to the oxidation of H_2S and NH_3 were able to resist at the moisture of 30% and maintain the RE higher than 80%.

Conclusions

According to the results obtained, it is recommended to maintain an EBRT of 25s and moisture of 40% for the design of an industrial biofiltration system, since, in these conditions, the bacterial growth was high and thus achieved the highest capacity to eliminate H_2S and NH_3. It also suggests that the microbial community of the compost bed was able to maintain a good performance at high loads and 30% of moisture content.

Acknowledgments

This work was financially supported by the Research Unit from the Universidad Santo Tomás (FODEIN 2019), Bogotá, Colombia. D. G. Vela-Aparicio acknowledges Colciencias for a doctoral fellowship (727 - Support to National Doctoral Program) and financial support to the work. Physicochemical analyses were supported by research assistant Angela Fernandez.

References

Ben Jaber M, Couvert A, Amrane A, Rouxel F, Le P, Dumont E (2016) Biofiltration of H 2 S in air — Experimental comparisons of original packing materials and modeling. Biochem Eng J 112:153–160 . doi: 10.1016/j.bej.2016.04.020

Iranpour R, Cox HHJ, Deshusses MA, Schroeder ED (2005) Literature review of air pollution control biofilters and biotrickling filters for odor and volatile organic compound removal. Environ Prog 24:254–267 . doi: 10.1002/ep.10077

Kim HS, Kim YJ, Chung JS, Xie Q (2002) Long-term operation of a biofilter for simultaneous removal of H2S and NH3. J Air Waste Manage Assoc 52:1389–1398 . doi: 10.1080/10473289.2002.10470871

Kim IS, Ivanov VN (2000) Detection of nitrifying bacteria in activated sludge by fluorescent in situ hybridization and fluorescence spectrometry. J Microbiol 16:425–430 . doi: 10.1023/A:1008949821236

Lewkowska P, Cieslik B, Dymerski T, Konieczka P, Namiesnik J (2016) Characteristics of odors emitted from municipal wastewater treatment plant and methods for their identification and deodorization techniques. Environ Res 151:573–586 . doi: 10.1016/j.envres.2016.08.030

Rene ER, Kennes C, Veiga MC (2013) Biofilters. In: Kennes C, Veiga MC (eds) Air Pollution Prevention and Control: Bioreactors and Bioenergy, First. John Wiley & Sons, Ltd., pp 60–72

Vela-Aparicio DG, Forero DF, Acevedo P, Brandão PFB, Hernández MA, Cabeza IO (2019) Evaluation of compost from chicken manure and lignocellulosic materials as packing material in a biofiltration system for the simultaneous removal of H 2 S and NH 3. In: HERAKLION 2019 7th International Conference on Sustainable Solid Waste Management. Heraklion,Crete Island, Greece, p Poster N° 133